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# Subminiature tubes-prediction of failure and life testing under normal and overload conditions

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Baltimore, Maryland; Johns Hopkins University

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SUBMINIATURE TUBES - PREDICTION OF FAILURE AND  
LIFE TESTING UNDER NORMAL AND OVERLOAD CONDITIONS

by

HORACE PHILLIPS McNEAL

An Essay

submitted to the Advisory Board

of The School of Engineering

of

The Johns Hopkins University

in conformity with the requirements for

the Degree of Master of Engineering.

Baltimore

Maryland

May 1949

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### References

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# SUBMINIATURE TUBES - PREDICTION OF FAILURE AND LIFE TESTING UNDER NORMAL AND OVERLOAD CONDITIONS

## Chapter I

### Introduction

The purpose of this investigation is threefold. First, to make static tests on subminiature tubes, collecting as much data as possible on their behavior at different values of heater voltage and at different values of plate voltage; and to compare uniformity of the same type tube made by two different manufacturers. Second, to make dynamic tests on the same tubes in a circuit which simulates their use in an actual amplifier. The purpose of these tests is to determine tube life, or changes in tube characteristics, under normal load and overload conditions. Third, to attempt to correlate the results of the static tests with the results of the dynamic tests and discover some



The purpose of this investigation is to determine the effect of the various factors mentioned above on the rate of growth of the young of the fish. The results of the investigation will be presented in a separate report.

method by which static testing may be used to accurately predict which tubes may fail under overload; or to prove that no simple criterion exists for such prediction.

The investigation was sponsored by the Telemetering Group of The Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland, which supplied the subminiature tubes to be tested, approximately 100 each of the following types:

a) Manufacturer "S" - Type 6K4-A General Purpose Triode, and b) Manufacturer "R" Type 6K608CX Triode.

The general description of the tests to be conducted was contained in a letter to the supervisor of the Telemetering Group from the gentlemen for whom the tests were run. It described the tests as follows: "The first phase will consist of a number of measurements of the parameters of the tubes, with various electrode voltages from normal to less





than normal. The second phase will consist of running the tubes under varying conditions of overload to determine life and types of failure. The final report will attempt to correlate the predicted life with the actual life under overload. It will also show the relative merits of the 6K4-A and the 6X50B".



## Chapter II

### Description of Static Tests

The static tests consisted of the following:

- a) Each tube was tested for internal short circuits.
- b) Tubes were operated at rated value of heater voltage (6.3 volts A.C.) and Grid Bias voltage (-2 volts). Plate voltage was set successively at 100%, 80%, 60%, 50%, and 33.3% rated value for Manufacturer "S" Tubes and at 100%, 83.5%, 66.7%, 50%, 33.3% rated value for Manufacturer "R" Tubes. At each value of plate voltage the following quantities were recorded: Grid Bias Voltage, Heater Voltage, Plate current, Heater current, Grid current, Transconductance.
- c) Tubes were operated at rated value of Plate Voltage (100volts D.C. for Manufacturer "S" Tubes, 120 volts D.C. for Manufacturer "R" Tubes). Heater voltage was set successively at 100%, 83.5%, 31.8% of rated Heater voltage (6.3

# Chapter II

1. Description of the Test

2. The test was conducted in the following manner:

3. The test was conducted in the following manner:

4. The test was conducted in the following manner:

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21. The test was conducted in the following manner:

22. The test was conducted in the following manner:



volts A. C.). At each value of heater voltage the following quantities were recorded: Plate Voltage, Grid Bias Voltage, Plate Current, Heater Current, Grid Current, Transconductance.

#### Description of Tube Testing Equipment Used For Static Tests

The static tests described above were performed in a Navy Type OD-5 Tester. A brief description of this equipment follows as it appears in the Instruction Pamphlet: Model OD-5 Vacuum Tube Analyzing Equipment Supply 110-120 volts 50-60 cycles. Manufacturer: Weston Electrical Instrument Corporation.

"In brief the Model OD equipment consists of the following apparatus: A plurality of vacuum tube sockets designed to accommodate 4 pin, 5 pin, 6 pin, 7 pin, 8 pin miniature and acorn tube bases; a transformer supplying 60 cycle power at one of

view as well as some other of similar  
nature the following description may be  
made: First, the building is a  
three-story, brick structure, with a  
transverse section.

Remains of the building are  
not visible here.

The entire area described above was  
occupied in a very large building,  
which was occupied by this company before  
as it appears in the foundation remains.  
The only other remains were the remains of  
the building which was built in 1880, and  
which was destroyed by fire in 1890.  
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several standard filament potentials; patch cords for connecting filament power to any pair of socket terminals; a power rectifier supplying filtered direct potential to a system of potentiometers and thence by way of patch cords, to any desired socket terminals; a plurality of electrical indicating instruments suitable for indicating potentials between socket terminals and currents flowing through socket terminals, and a plurality of vacuum tube sockets interconnected with indicating lamps designed to indicate the presence of short circuited tube elements."

"The Model OD equipment measures transconductance by measuring the alternating current produced in the plate circuit by a 60 cycle signal applied to the grid of the tube under test. The grid signal has an effective value of one volt and as transconductance is the ratio of the value of alternating plate current to the value of the alternating grid signal which produced it, it is evident

about 1910, and since then, the number of cases has increased steadily. The disease is now a serious public health problem in many parts of the world. It is caused by a virus which is spread by mosquitoes. The disease is characterized by a high fever, headache, and a rash. It is usually fatal, but in some cases it can be cured. The disease is most common in tropical and subtropical regions. It is a major cause of death and disability in many of these areas. The disease is also a major cause of economic loss in many of these areas. It is a major cause of death and disability in many of these areas. It is a major cause of death and disability in many of these areas.

On the 10th of August 1944, the following was received from the Ministry of the Interior, Berlin:

that the instrument which measured the alternating component of plate current may be calibrated in terms of micromhos of transconductance instead of microamperes of alternating current."

Figure 1 is a block diagram of this tester.

For the purpose of giving qualitative information on the tests, it will be necessary to introduce the identification system used on the tubes. The tubes were assigned a two letter symbol followed by a number. The first letter designates the manufacturer - "S" denoting Manufacturer "S" and "R" denoting Manufacturer "R"; the second letter identifies the lot number - there being three lots of Manufacturer "S" Tubes designated "SA", "SB", and "SC", and four lots of Manufacturer "R" Tubes designated "RA", "RB", "RC", and "RD". Table I in Appendix I identifies the tubes by manufacturers' lot numbers.

In Tables II through VIII of Appendix I

[illegible][illegible]



# BLOCK DIAGRAM MODEL OD TESTER

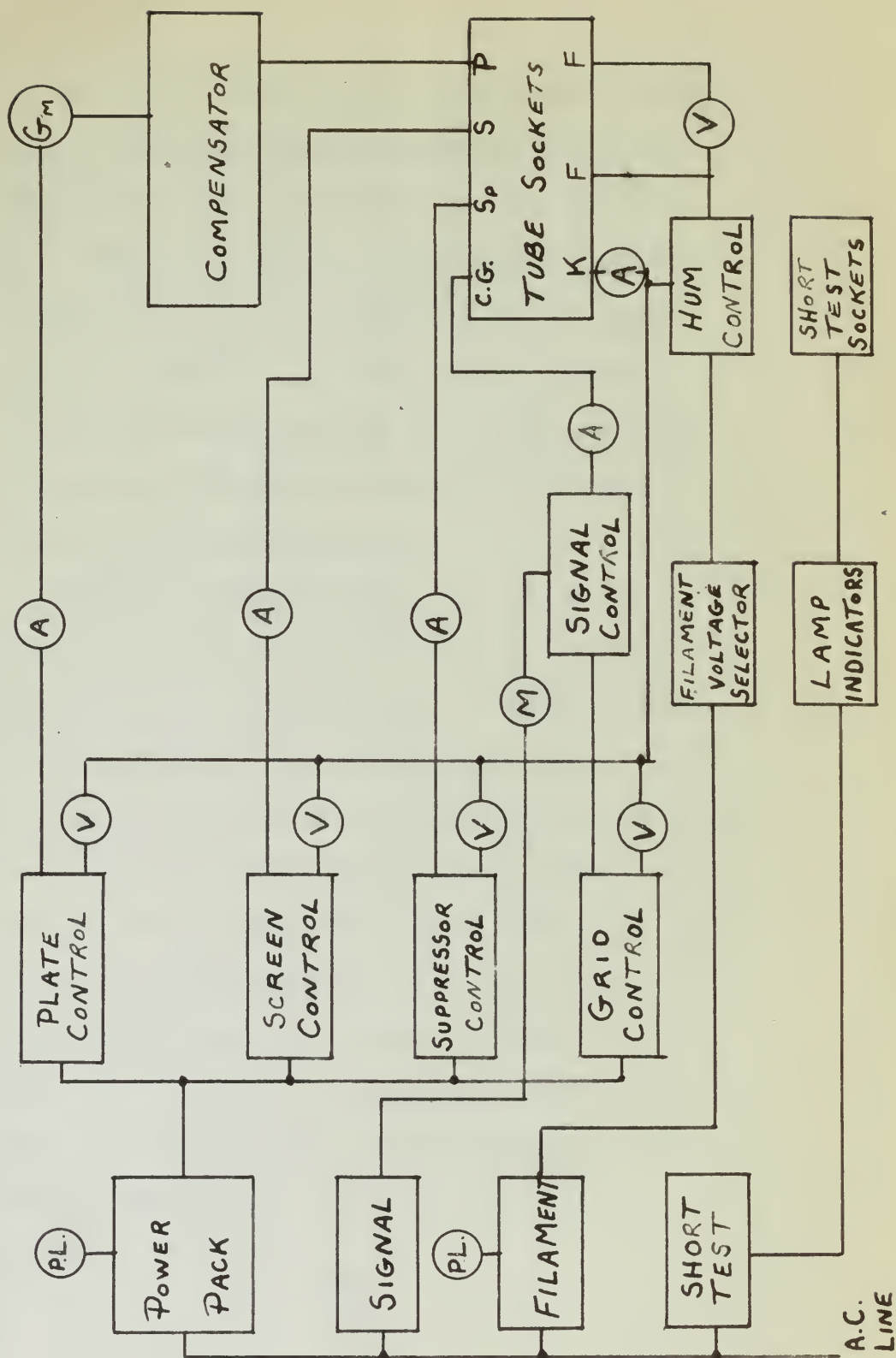


FIGURE 1



are tabulated values of Plate Current, Transconductance, and Plate Resistance for each tube for 100% Plate Voltage and Heater Voltage. Plate resistances were computed by the formula  $r_p = \frac{\Delta E_{plate} \times 1000}{\Delta I_{plate}}$  where  $\Delta E_{plate}$  was = 20 volts in each case (i. e. 100 to 80 volts for Manufacturer "S" Tubes and 120 to 100 volts for Manufacturer "R" Tubes).  $I_{plate}$  was in milliamperes.

While a value of  $\Delta E_{plate}$  of 20 volts may seem too large an increment to take in computing plate resistances, it will be seen from the Characteristic Curves (Plates I through VII) that the slope of the curves from 100 to 80 volts in the case of Manufacturer "S" Tubes, and from 120 to 100 volts in the case of Manufacturer "R" Tubes is substantially a constant value. This being the case the twenty volt increment became a reasonable one to take since it eliminated an extra voltage reading on each tube.



are tabulated values of plate current, trans-  
conductance, and plate resistance for each  
tube for 100, 150, 200, 250, and 300 volts.  
Also, these values are computed by the  
formula  $\mu = \frac{g_m \times R_p}{\Delta E_b}$  where  $\Delta E_b$   
was 20 volts in each case (i. e. 100 to  
80 volts for 6X4, 150 to 130 for 6Y6, and 200  
to 180 for 6Z5).  
These are in milliamperes.  
While a value of  $\mu$  of 20 is  
very good for large an increase in  $E_b$  is  
computed, the plate resistance, it will be seen  
from the characteristic curves (Fig. 1)  
through will show the slope of the curves  
from 100 to 80 volts in the case of 6X4,  
from 150 to 130 for 6Y6, and from 200 to 180 for  
6Z5. The case of 6X4 is shown in Fig. 1.  
The case of 6Y6 is shown in Fig. 2.  
The case of 6Z5 is shown in Fig. 3.  
The case of 6X4 is shown in Fig. 4.  
The case of 6Y6 is shown in Fig. 5.  
The case of 6Z5 is shown in Fig. 6.  
The case of 6X4 is shown in Fig. 7.  
The case of 6Y6 is shown in Fig. 8.  
The case of 6Z5 is shown in Fig. 9.

The manufacturers give the following as  
 "Typical Operating Conditions" for the Type  
 6K4-A and CK608CX Tubes:

Manufacturer "S" Type 6K4-A Tubes

Heater Voltage	6.3	6.3	Volts
Heater Current	150	150	Ma
Plate Voltage	100	200	Volts
Grid Bias Voltage	-2	-8	Volts
Plate Current	13.0	11.5	Ma
Amplification Factor	20	16	
Plate Resistance	3640	4650	Ohms
Grid Voltage for Plate current cut- off to 10 amp.	-14	-30	Volts
Transconductance	5500	3450	Micromhos

Manufacturer "R" Type CK608CX Tubes

Heater Voltage	6.3	Volts
Heater Current	200	Ma
Plate Voltage	120	Volts
Grid Bias Voltage	-2	Volts
Plate Current	9.0	Ma *
Transconductance	5000	Micromhos
Amplification Factor	25	

\* Manufacturer's Curve Plots this as 8.3 Ma.

EX-4-a and EX-600-1 tubes;  
"typical operating conditions" for the type  
The manufacturers give the following as

MANUFACTURED BY "A" TYPE ONE-A TUBES

Plate Voltage	Grid Bias Voltage	Plate Current	Amplification Factor	Plate Resistance	Grid Voltage	Plate Current	Amplification Factor	Plate Resistance	Grid Voltage	Plate Current	Amplification Factor	Plate Resistance
250	-5	12.0	20	4500	0	12.0	20	4500	0	12.0	20	4500
250	-10	11.8	20	4500	0	11.8	20	4500	0	11.8	20	4500
250	-15	11.5	20	4500	0	11.5	20	4500	0	11.5	20	4500
250	-20	11.2	20	4500	0	11.2	20	4500	0	11.2	20	4500
250	-25	11.0	20	4500	0	11.0	20	4500	0	11.0	20	4500
250	-30	10.8	20	4500	0	10.8	20	4500	0	10.8	20	4500
250	-35	10.5	20	4500	0	10.5	20	4500	0	10.5	20	4500
250	-40	10.2	20	4500	0	10.2	20	4500	0	10.2	20	4500
250	-45	10.0	20	4500	0	10.0	20	4500	0	10.0	20	4500
250	-50	9.8	20	4500	0	9.8	20	4500	0	9.8	20	4500
250	-55	9.5	20	4500	0	9.5	20	4500	0	9.5	20	4500
250	-60	9.2	20	4500	0	9.2	20	4500	0	9.2	20	4500
250	-65	9.0	20	4500	0	9.0	20	4500	0	9.0	20	4500
250	-70	8.8	20	4500	0	8.8	20	4500	0	8.8	20	4500
250	-75	8.5	20	4500	0	8.5	20	4500	0	8.5	20	4500
250	-80	8.2	20	4500	0	8.2	20	4500	0	8.2	20	4500
250	-85	8.0	20	4500	0	8.0	20	4500	0	8.0	20	4500
250	-90	7.8	20	4500	0	7.8	20	4500	0	7.8	20	4500
250	-95	7.5	20	4500	0	7.5	20	4500	0	7.5	20	4500
250	-100	7.2	20	4500	0	7.2	20	4500	0	7.2	20	4500

圖 6-6-2 鋼筋的種類及規格

	Amplification Factor	Frequency Response
Plate Current	0.5 mA *	
Grid Bias Voltage	-5 Volts	
Plate Voltage	180 Volts	
Screen Grid Voltage	200 V	
Control Grid Voltage	0.5 Volts	

• *W. M. Patterson's "Guns, Boys, and Streets"* pp. 100-101.

A comparison of the average values of  $I_p$  plate and  $E_M$  with the Manufacturer's Typical Operating Values is given in the following table ( $r_p$  is not included here because Manufacturer "R" Tube Characteristic Sheet quotes no value of  $r_p$ ).

	Manufacturers Typical $I_p$ milliamps	Actual average $I_p$ milliamps	Diff.
Manufacturer			
"S" Tubes	13.0	11.2	-1.8
	13.0	15.6	+2.6
	13.0	11.3	-1.7
Manufacturer			
"R" Tubes	9.0	11.7	+2.7
	9.0	11.0	+2.0
	9.0	9.0	0.0



A comparison of the error values of 1  
also and with the manufacturer's typical  
operating values is given in the following  
table (r is not included here because  
manufacturer's "r" value characteristics are  
given as values of r<sub>1</sub>).

Year	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100
1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	



	Manufac. Typical $\mu m$ <u>michomho</u>	Actual average <u><math>\mu</math> michomho</u>	Diff. <u>_____</u>
Manufacturer			
"S" Tubes	5500	3695	-1805
	5500	4320	-1180
	5500	3675	-1825
Manufacturer			
"R" Tubes	5000	4150	- 850
	5000	3980	-1010
	5000	3660	-1340

In the next table below the average variations from the mean values of Plate current, plate resistance, and transconductance are given:

Manufacturer	<u><math>I_{plate}</math></u>	<u><math>r_p</math></u>	<u><math>\mu m</math></u>	<u>Number good tubes in lot</u>
"S" Tubes	1.77	470	312	<u>14</u>
	1.44	216.2	214.7	33
	1.56	408	292	<u>31</u>
			Total	98
Manufacturer				
"R" Tubes	.98	316	226.5	9
	1.01	444	215	26
	1.33	892	281	23

Year	Typical in	Typical in	Typical in
1950	1950	1950	1950
1951	1951	1951	1951
1952	1952	1952	1952
1953	1953	1953	1953
1954	1954	1954	1954
1955	1955	1955	1955
1956	1956	1956	1956
1957	1957	1957	1957
1958	1958	1958	1958
1959	1959	1959	1959
1960	1960	1960	1960

[illegible]

	<u>I<sub>plate</sub></u>	<u>r<sub>p</sub></u>	<u>Em</u>	<u>Number good tubes in lot</u>
Manufacturer				
"R" Tubes	.72	266	195	<u>40</u>

Total	98
-------	----

	<u>number bad tubes in lot</u>	<u>% good tubes</u>
Manufacturer		
"S" Tubes	<u>1</u>	<u>97.1</u>

2	94.3
---	------

Total	<u>4</u> 7	88.6
-------	---------------	------

Manufacturer		
"R" Tubes	1	90
	0	100
	1	96
	<u>0</u>	100

Total	2
-------	---

It will be observed that of 105 "S" Tubes tested, 98 were good - percentage 93.4; while for 100 "R" Tubes tested, 98 were good - percentage 98.

Weighted value of average variation from mean value of  $I_{plate}$  is computed in Table IX of Appendix I.

Number of Tubes in lot	Lot	Number of Tubes	Percentage
40	100	72	18
40	Total		

Number of Tubes	Number of Tubes in lot	Percentage
1	40	2.5
2	40	5.0
3	40	7.5
4	40	10.0
5	40	12.5
6	40	15.0
7	40	17.5
8	40	20.0
9	40	22.5
10	40	25.0
11	40	27.5
12	40	30.0
13	40	32.5
14	40	35.0
15	40	37.5
16	40	40.0
17	40	42.5
18	40	45.0
19	40	47.5
20	40	50.0
21	40	52.5
22	40	55.0
23	40	57.5
24	40	60.0
25	40	62.5
26	40	65.0
27	40	67.5
28	40	70.0
29	40	72.5
30	40	75.0
31	40	77.5
32	40	80.0
33	40	82.5
34	40	85.0
35	40	87.5
36	40	90.0
37	40	92.5
38	40	95.0
39	40	97.5
40	40	100.0
41	40	102.5
42	40	105.0
43	40	107.5
44	40	110.0
45	40	112.5
46	40	115.0
47	40	117.5
48	40	120.0
49	40	122.5
50	40	125.0
51	40	127.5
52	40	130.0
53	40	132.5
54	40	135.0
55	40	137.5
56	40	140.0
57	40	142.5
58	40	145.0
59	40	147.5
60	40	150.0
61	40	152.5
62	40	155.0
63	40	157.5
64	40	160.0
65	40	162.5
66	40	165.0
67	40	167.5
68	40	170.0
69	40	172.5
70	40	175.0
71	40	177.5
72	40	180.0
73	40	182.5
74	40	185.0
75	40	187.5
76	40	190.0
77	40	192.5
78	40	195.0
79	40	197.5
80	40	200.0
81	40	202.5
82	40	205.0
83	40	207.5
84	40	210.0
85	40	212.5
86	40	215.0
87	40	217.5
88	40	220.0
89	40	222.5
90	40	225.0
91	40	227.5
92	40	230.0
93	40	232.5
94	40	235.0
95	40	237.5
96	40	240.0
97	40	242.5
98	40	245.0
99	40	247.5
100	40	250.0
101	40	252.5
102	40	255.0
103	40	257.5
104	40	260.0
105	40	262.5
106	40	265.0
107	40	267.5
108	40	270.0
109	40	272.5
110	40	275.0
111	40	277.5
112	40	280.0
113	40	282.5
114	40	285.0
115	40	287.5
116	40	290.0
117	40	292.5
118	40	295.0
119	40	297.5
120	40	300.0
121	40	302.5
122	40	305.0
123	40	307.5
124	40	310.0
125	40	312.5
126	40	315.0
127	40	317.5
128	40	320.0
129	40	322.5
130	40	325.0
131	40	327.5
132	40	330.0
133	40	332.5
134	40	335.0
135	40	337.5
136	40	340.0
137	40	342.5
138	40	345.0
139	40	347.5
140	40	350.0
141	40	352.5
142	40	355.0
143	40	357.5
144	40	360.0
145	40	362.5
146	40	365.0
147	40	367.5
148	40	370.0
149	40	372.5
150	40	375.0
151	40	377.5
152	40	380.0
153	40	382.5
154	40	385.0
155	40	387.5
156	40	390.0
157	40	392.5
158	40	395.0
159	40	397.5
160	40	400.0
161	40	402.5
162	40	405.0
163	40	407.5
164	40	410.0
165	40	412.5
166	40	415.0
167	40	417.5
168	40	420.0
169	40	422.5
170	40	425.0
171	40	427.5
172	40	430.0
173	40	432.5
174	40	435.0
175	40	437.5
176	40	440.0
177	40	442.5
178	40	445.0
179	40	447.5
180	40	450.0
181	40	452.5
182	40	455.0
183	40	457.5
184	40	460.0
185	40	462.5
186	40	465.0
187	40	467.5
188	40	470.0
189	40	472.5
190	40	475.0
191	40	477.5
192	40	480.0
193	40	482.5
194	40	485.0
195	40	487.5
196	40	490.0
197	40	492.5
198	40	495.0
199	40	497.5
200	40	500.0
201	40	502.5
202	40	505.0
203	40	507.5
204	40	510.0
205	40	512.5
206	40	515.0
207	40	517.5
208	40	520.0
209	40	522.5
210	40	525.0
211	40	527.5
212	40	530.0
213	40	532.5
214	40	535.0
215	40	537.5
216	40	540.0
217	40	542.5
218	40	545.0
219	40	547.5
220	40	550.0
221	40	552.5
222	40	555.0
223	40	557.5
224	40	560.0
225	40	562.5
226	40	565.0
227	40	567.5
228	40	570.0
229	40	572.5
230	40	575.0
231	40	577.5
232	40	580.0
233	40	582.5
234	40	585.0
235	40	587.5
236	40	590.0
237	40	592.5
238	40	595.0
239	40	597.5
240	40	600.0
241	40	602.5
242	40	605.0
243	40	607.5
244	40	610.0
245	40	612.5
246	40	615.0
247	40	617.5
248	40	620.0
249	40	622.5
250	40	625.0
251	40	627.5
252	40	630.0
253	40	632.5
254	40	635.0
255	40	637.5
256	40	640.0
257	40	642.5
258	40	645.0
259	40	647.5
260	40	650.0
261	40	652.5
262	40	655.0
263	40	657.5
264	40	660.0
265	40	662.5
266	40	665.0
267	40	667.5
268	40	670.0
269	40	672.5
270	40	675.0
271	40	677.5
272	40	680.0
273	40	682.5
274	40	685.0
275	40	687.5
276	40	690.0
277	40	692.5
278	40	695.0
279	40	697.5
280	40	700.0
281	40	702.5
282	40	705.0
283	40	707.5
284	40	710.0
285	40	712.5
286	40	715.0
287	40	717.5
288	40	720.0
289	40	722.5
290	40	725.0
291	40	727.5
292	40	730.0
293	40	732.5
294	40	735.0
295	40	737.5
296	40	740.0
297	40	742.5
298	40	745.0
299	40	747.5
300	40	750.0
301	40	752.5
302	40	755.0
303	40	757.5
304	40	760.0
305	40	762.5
306	40	765.0
307	40	767.5
308	40	770.0
309	40	772.5
310	40	775.0
311	40	777.5
312	40	780.0
313	40	782.5
314	40	785.0
315	40	787.5
316	40	790.0
317	40	792.5
318	40	795.0
319	40	797.5
320	40	800.0
321	40	802.5
322	40	805.0
323	40	807.5
324	40	810.0
325	40	812.5
326	40	815.0
327	40	817.5
328	40	820.0
329	40	822.5
330	40	825.0
331	40	827.5
332	40	830.0
333	40	832.5
334	40	835.0
335	40	837.5
336	40	840.0
337	40	842.5
338	40	845.0
339	40	847.5
340	40	850.0
341	40	852.5
342	40	855.0
343	40	857.5
344	40	860.0
345	40	862.5
346	40	865.0
347	40	867.5
348	40	870.0
349	40	872.5
350	40	875.0
351	40	877.5
352	40	880.0
353	40	882.5
354	40	885.0
355	40	887.5
356	40	890.0
357	40	892.5
358	40	895.0
359	40	897.5
360	40	900.0
361	40	902.5
362	40	905.0
363	40	907.5
364	40	910.0
365	40	912.5
366	40	915.0
367	40	917.5
368	40	920.0
369	40	922.5
370	40	925.0
371	40	927.5
372	40	930.0
373	40	932.5
374	40	935.0
375	40	937.5
376	40	940.0
377	40	942.5
378	40	945.0
379	40	947.5
380	40	950.0
381	40	952.5
382	40	955.0
383	40	957.5
384	40	960.0
385	40	962.5
386	40	965.0
387	40	967.5
388	40	970.0
389	40	972.5
390	40	975.0
391	40	977.5
392	40	980.0
393	40	982.5
394	40	985.0
395	40	987.5
396	40	990.0
397	40	992.5
398	40	



Similar computations give the following weighted-in variations from mean value of  $E_m$  and  $r_p$ .

	Weighted var. of $E_m$	Weighted var. of $r_p$	Weighted var. of $I_{plate}$
Manufacturer "S" Tubes	272.5	520.5	1.591
Manufacturer "R" Tubes	223.0	501.0	.963

The results above lead to the conclusion that Manufacturer "R" CK608CX Tube is more uniform in static characteristics from tube to tube than is the Manufacturer "S" 6K4-A Tube. It is realized that the comparison given in the three tables above is not a measure of the relative merits of the tubes on an absolute basis. It does demonstrate clearly, however, that the manufacturers of the "S" tubes are apt to overrate their tubes more than the manufacturers of the "R" Tubes.

The tubes which were classified as bad



Similar computations for the following  
 are indicated in parentheses from which values  
 of  $\alpha$  and  $\beta$  are

Manufacturer	Weighted avg. of $\alpha$ %	Weighted avg. of $\beta$ %	Weighted avg. of $\gamma$ %
"A" Tubes	55.5	50.5	1.001
"B" Tubes	53.5	50.5	.993

The results above lead to the conclusion  
 that since Manufacturer "A" E9000X tube is  
 more uniform in static characteristics from  
 tube to tube than is the Manufacturer "B"  
 E9000 tube. It is realized that the above  
 periods given in the above tables above are  
 not a measure of the relative merits of the  
 tubes on an absolute basis. It does become  
 apparent, however, that the manufacturer  
 of the "B" tubes are apt to overstate  
 their claims more than the manufacturer of  
 the "A" tubes.

The tubes which were classified as bad

tubes showed the following faults on being tested:

Tubes SA-28, SB-19, SC-8 indicated no internal short circuits, but each drew large excess heater current at rated value of heater voltage.

Tubes SB-33, SC-12, RC-21 drew five percent or less of rated value of plate current at rated value of plate voltage.

Tube SC-15 indicated several internal short circuits, and drew large excess heater current at rated value of heater voltage.

Tube SC-29 drew approximately 50% excess heater current at rated value of heater voltage. The plate current was approximately two percent of rated value at rated value of plate voltage.

Tube RA-7 indicated an internal short circuit from the grid to the heater. It drew a large grid current when the grid bias voltage was applied.

which showed the following results on being

tested:

Tube 20-22, 20-23, 20-24 indicated no  
internal short circuits, but each drew large  
excess heater current at rated value of plate  
or voltage.

Tube 20-25, 20-26, 20-27 drew five per-  
cent on loss of rated value of plate current  
at rated value of plate voltage.

Tube 20-28 indicated several internal  
short circuits, and drew large excess heater  
current at rated value of heater voltage.

Tube 20-29 drew approximately 80% of  
rated heater current at rated value of heater  
voltage. The plate current was approximately  
two percent of rated value at rated value of  
plate voltage.

Tube 20-30 indicated an internal short  
circuit from the grid to the heater. It  
drew a large grid current when the grid beam  
voltage was applied.

Comparison of Plate Characteristics of  
Manufacturer "S" and Manufacturer "R" Tubes

From the tests made on the OD Tester, it is possible to plot Plate Characteristic Curves for a grid bias of -2 volts. A plot of the average Plate Characteristic for each tube lot, the Manufacturers Plate Characteristic, and the characteristic of the high and low tube in each lot has been made on Plates I through VII which follow.



Department of State, Washington, D.C.

from the facts made in the 10 years,  
it is possible to find that the  
curve for a 100 year life is  
of the same type characteristic for each  
case. The characteristic life of the  
steel, and the characteristic of the life  
of the steel in each case has been made on these  
figures.



$I_{\text{PLATE}}$  - MILLIAMPS

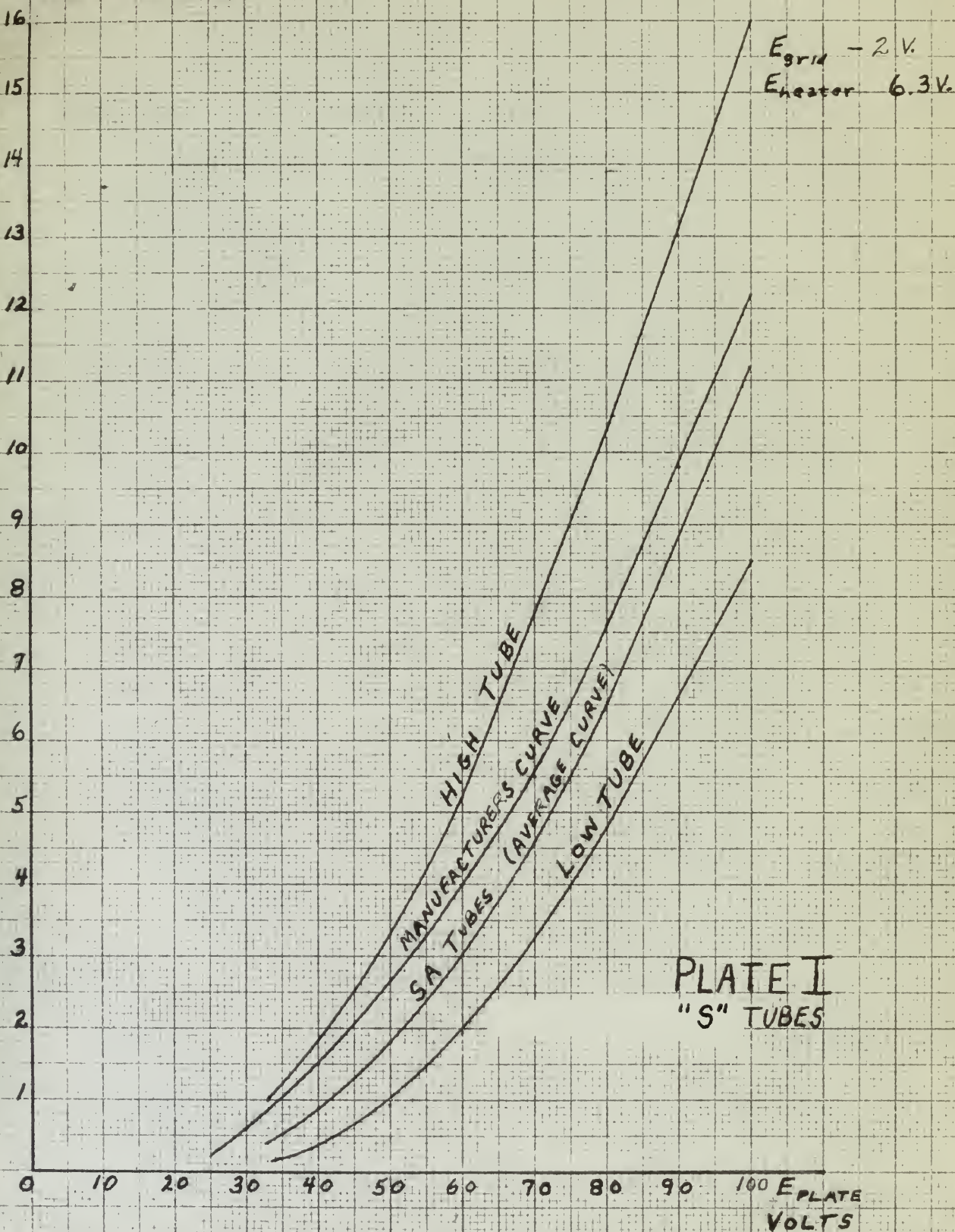


PLATE I  
"S" TUBES



$I_{\text{PLATE}}$  - MILLIAMPS

18

17

16

15

14

13

12

11

10

9

8

7

6

5

4

3

2

1

$E_{\text{GRID}}$  -2 V.  
 $E_{\text{HEATER}}$  6.3 V.

HIGH TUBE

SB TUBES (AVERAGE CURVE)

MANUFACTURERS CURVE

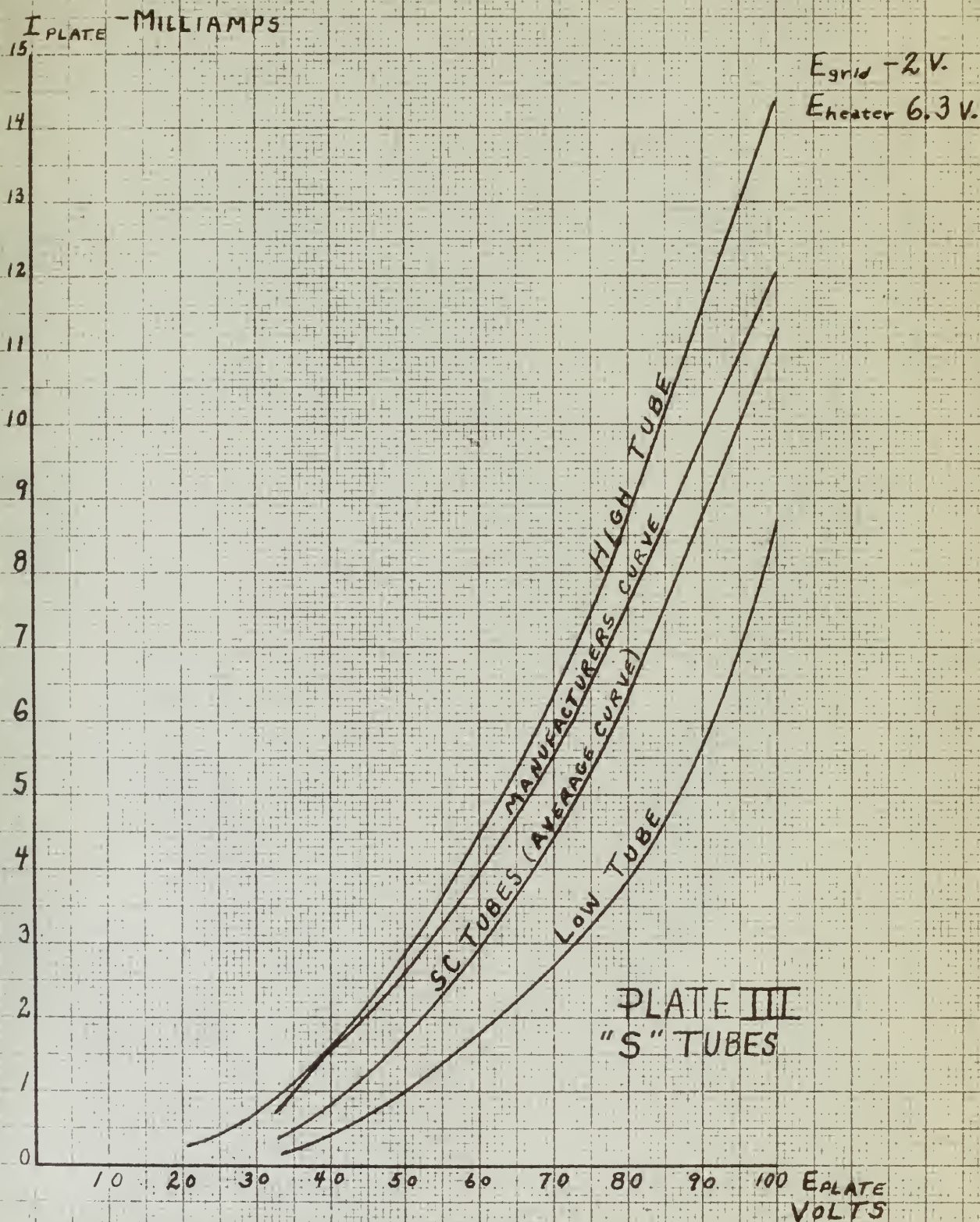
LOW TUBE

PLATE II  
"S" TUBES

0 10 20 30 40 50 60 70 80 90 100  $E_{\text{PLATE}}$  VOLTS

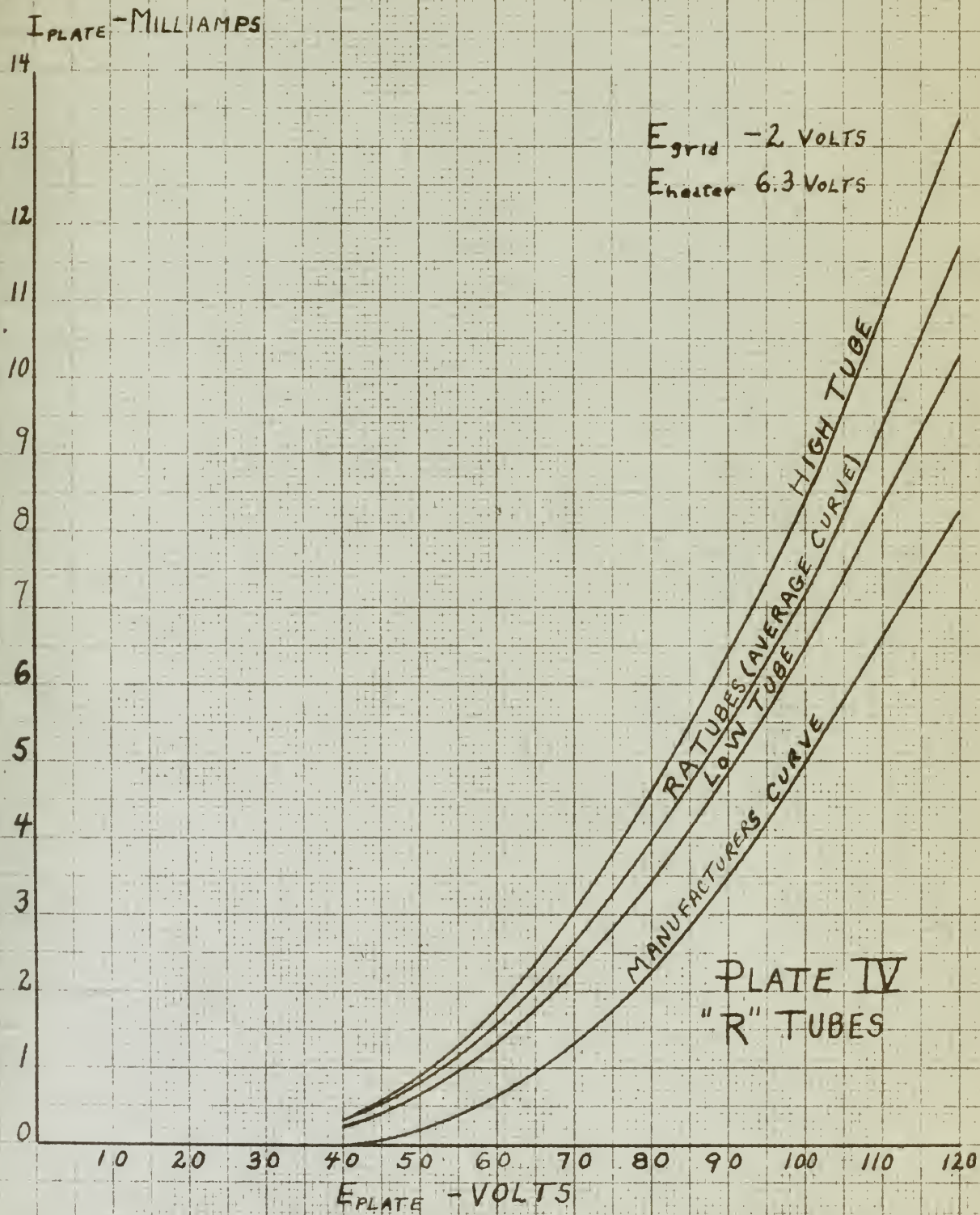






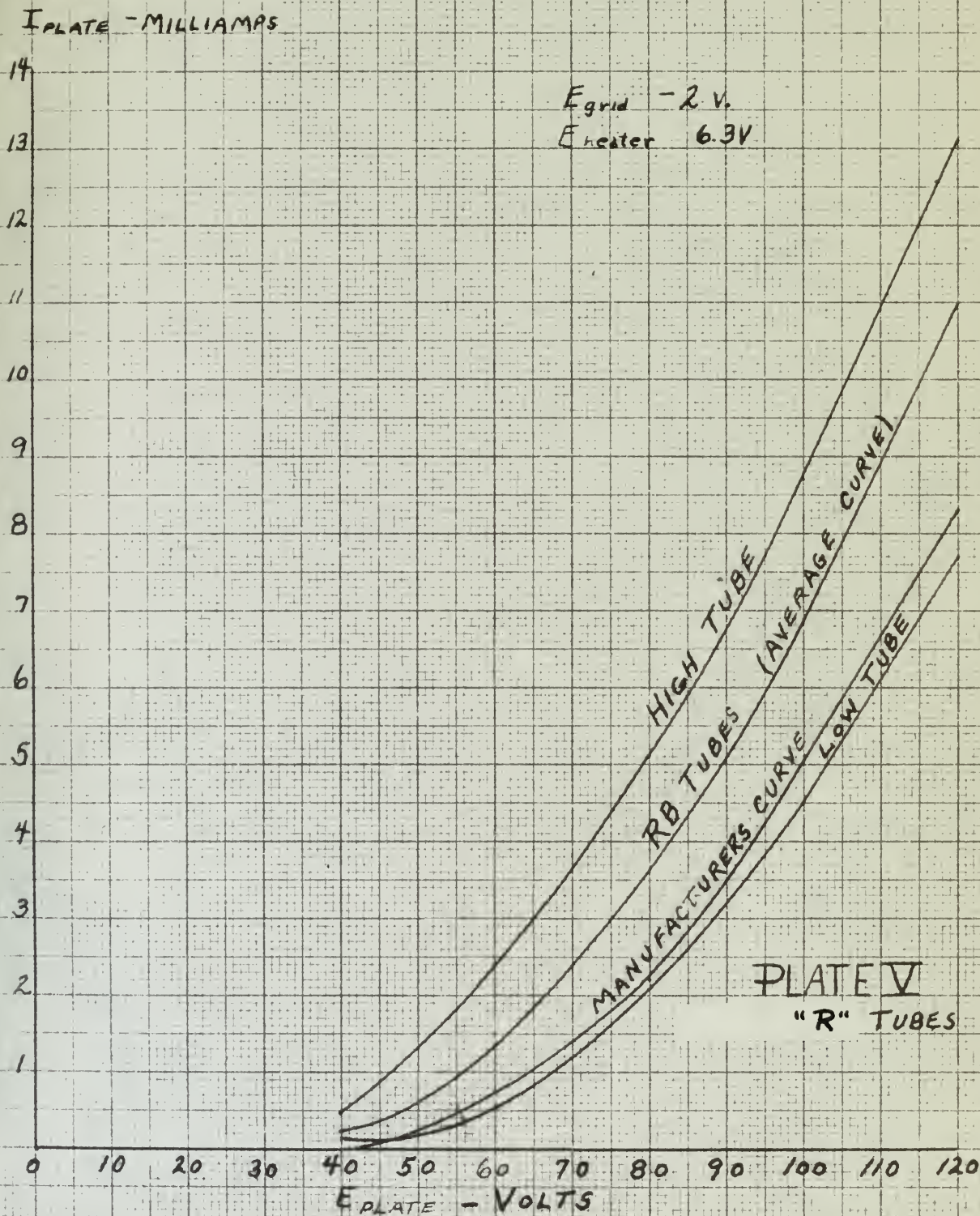








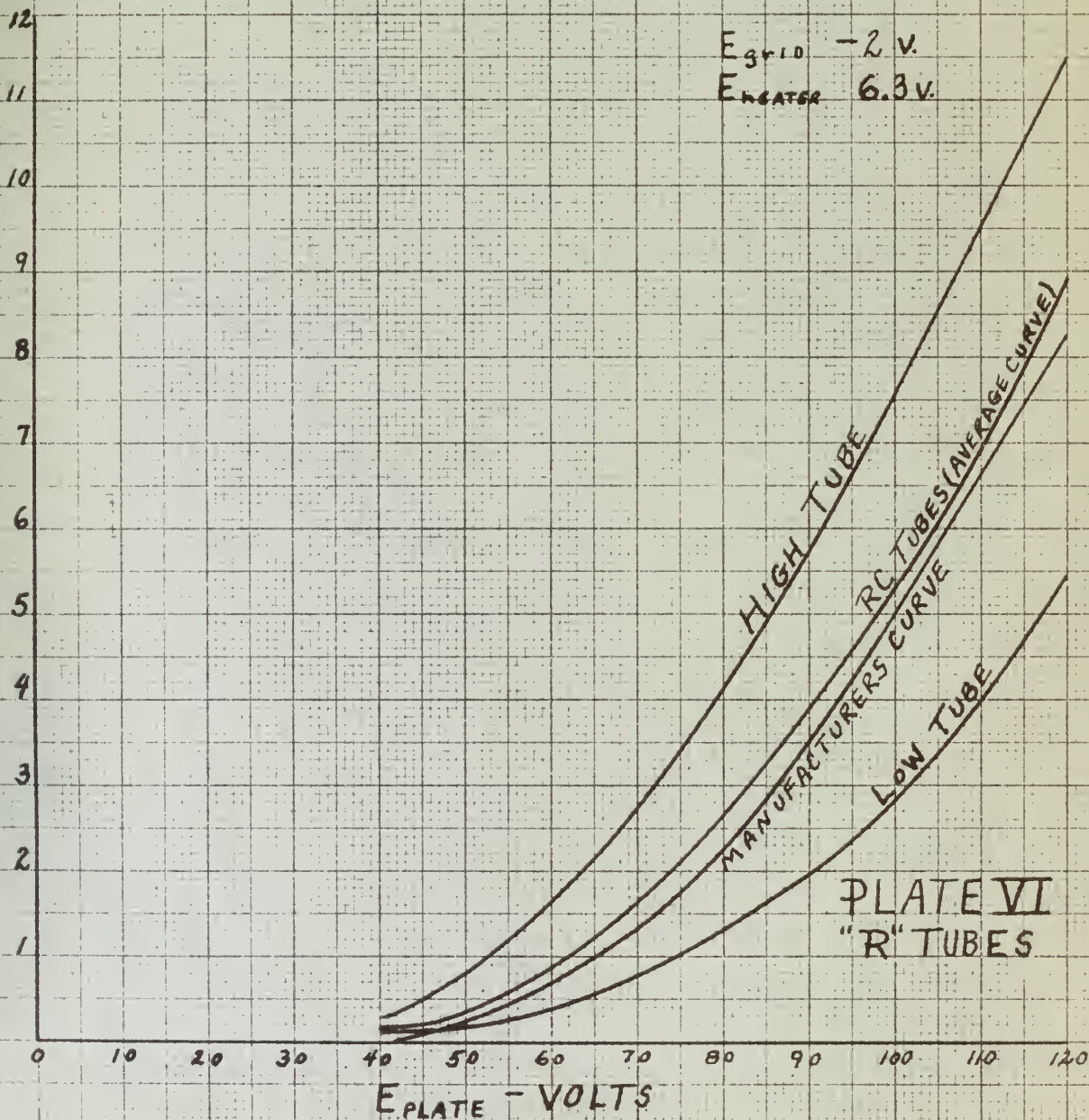






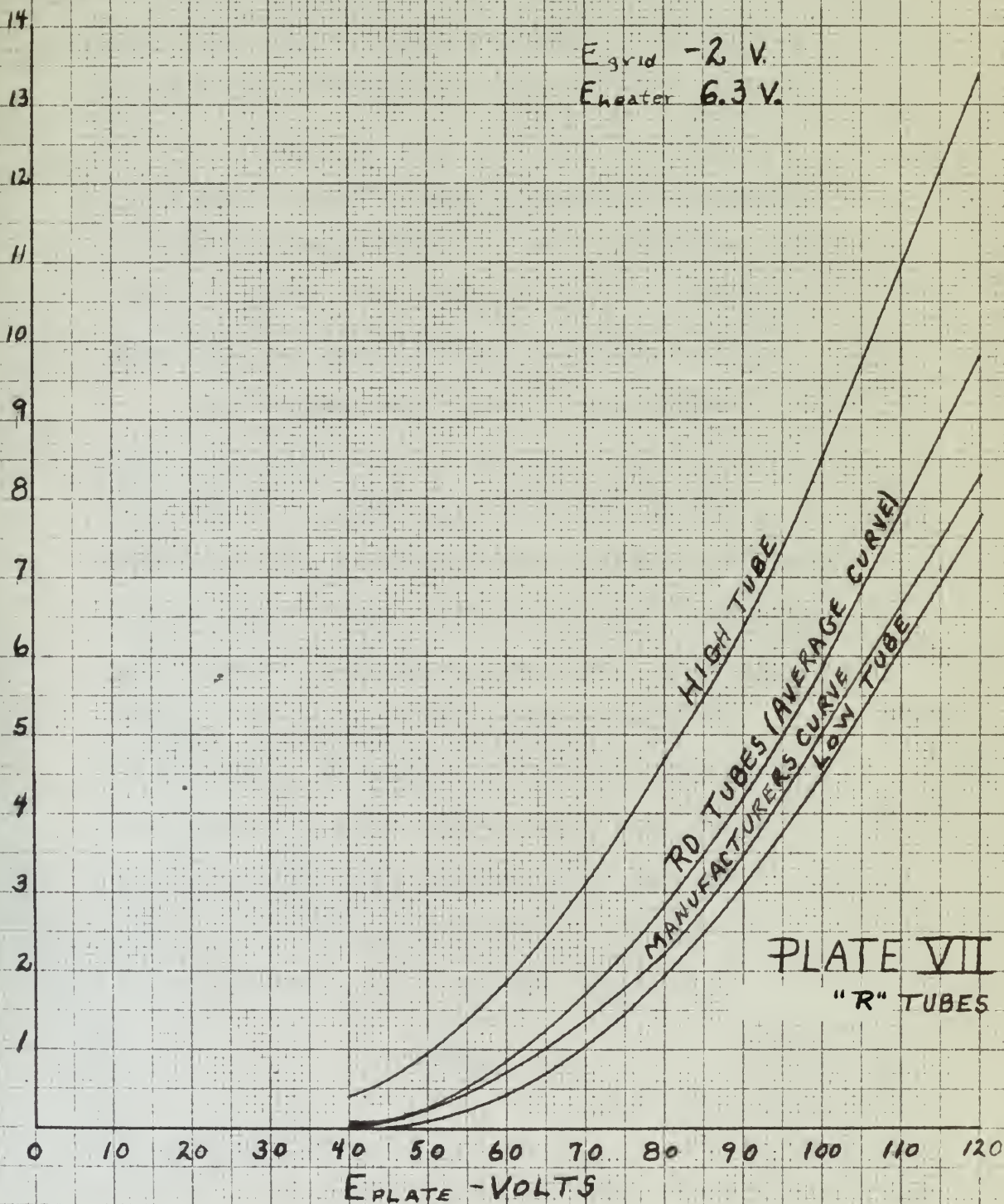


$I_{\text{PLATE}}$  - MILLIAMPS





$I_{\text{PLATE}}$  - MILLIAMPS







Examination of the curves in Plates I through VII shows two important points about the tubes. First, the average characteristic curve for the Manufacturer "R" Tubes is in each case higher than the Manufacturers Curve. In the case of the Manufacturer "S" Tubes in two cases out of three, it is lower than the manufacturer's curve. Secondly, the spread between high and low tube in a lot is greatest for Manufacturer "S" Tubes Lot SA.

One interesting point in connection with the static tests was the appearance in some tubes of small grid currents of the order of 100 to 700 microamps when heater voltage was set at 6.3 volts and no grid bias nor plate supply voltage was applied. This grid current was present in approximately 40% of the tubes of each manufacture. The tubes in which this grid current appeared tested in general above the average values of plate current and transconductance. For example in one lot this grid current appeared in 10



Examination of the curves in Figure 1 through VII shows two important points about the tubes. First, the average characteristics of the curves for the "Hannaford" and "Hannaford" tubes is in each case higher than the characteristics of the "Hannaford" tubes. In the case of the "Hannaford" tubes in two cases out of three, it is lower than the characteristics of the "Hannaford" tubes. Secondly, the spread between high and low values in a lot is greatest for "Hannaford" tubes (Lot 24). One interesting point in connection with the above facts was the appearance in some tubes of small grid currents of the order of 100 to 500 microamps when heater voltage was set at 4.5 volts and no grid bias nor plate supply voltage was applied. This grid current was present in approximately 40% of the tubes of each manufacturer. The tubes in which this grid current appeared tested in general above the average values of plate current and transconductance. For example in one lot 70% of the tubes appeared in 10

of 55 tubes. The average  $I_{plate}$  for these 10 tubes was 12.9 m.a. compared with an average value of 11.3 m.a. for the entire lot. The average  $g_m$  for these same 10 tubes was 4130 micromhos compared to 3675 micromhos for the entire lot.

Tubes in which the grid current appears probably have cathodes of better emission characteristics than those of the tubes in which this current does not appear.



### CHAPTER III

#### DESCRIPTION OF DYNAMIC TESTS

The dynamic tests were made to simulate the performance of an amplifier tube in a very high frequency F-M transmitter. A circuit diagram of the transmitter is given as Figure 2. Specifications for the transmitter are as follows:

R.F. Output Impedance      51.5 ohms

Tuning Range              209 mc to 227 mc.

Nominal Power Output      0.5 watt

#### Typical Operation:

Plate Supply Voltage      130 V.D.C.    115 V.D.C.

Plate Current              45 ma          35 ma

Heater Current              0.45 amp.    0.45 amp.

Power Output (51.5 ohm) 0.5 watt    0.5 watt

To reproduce exactly the conditions which exist in the amplifier of this transmitter, it would be necessary to build the complete unit according to specifications taking necessary precautions to shield the



# DESCRIPTION OF DYNAMIC TESTS

The dynamic tests were made to illustrate the performance of an amplifier when in a very high frequency V-M transmitter. A typical diagram of the transmitter is given as figure 2. Specifications for the transmitter are as follows:

1.5. Output Impedance	21.6 ohms
Power Range	200 to 2500 w.
Terminal Power Output	0.1 m watt
Typical Operation:	
Wave Supply Voltage	120 V.C.P. 115 V.C.P.
Wave Current	25 ma
Waveform	0.15 amp. 0.15 amp.
Power Output (21.6 ohm) 0.1 m watt	0.1 m watt

To reproduce exactly the conditions which exist in the amplifier of this transmitter, it would be necessary to build the amplifier with feedback in operation and before necessary precautions to shield the

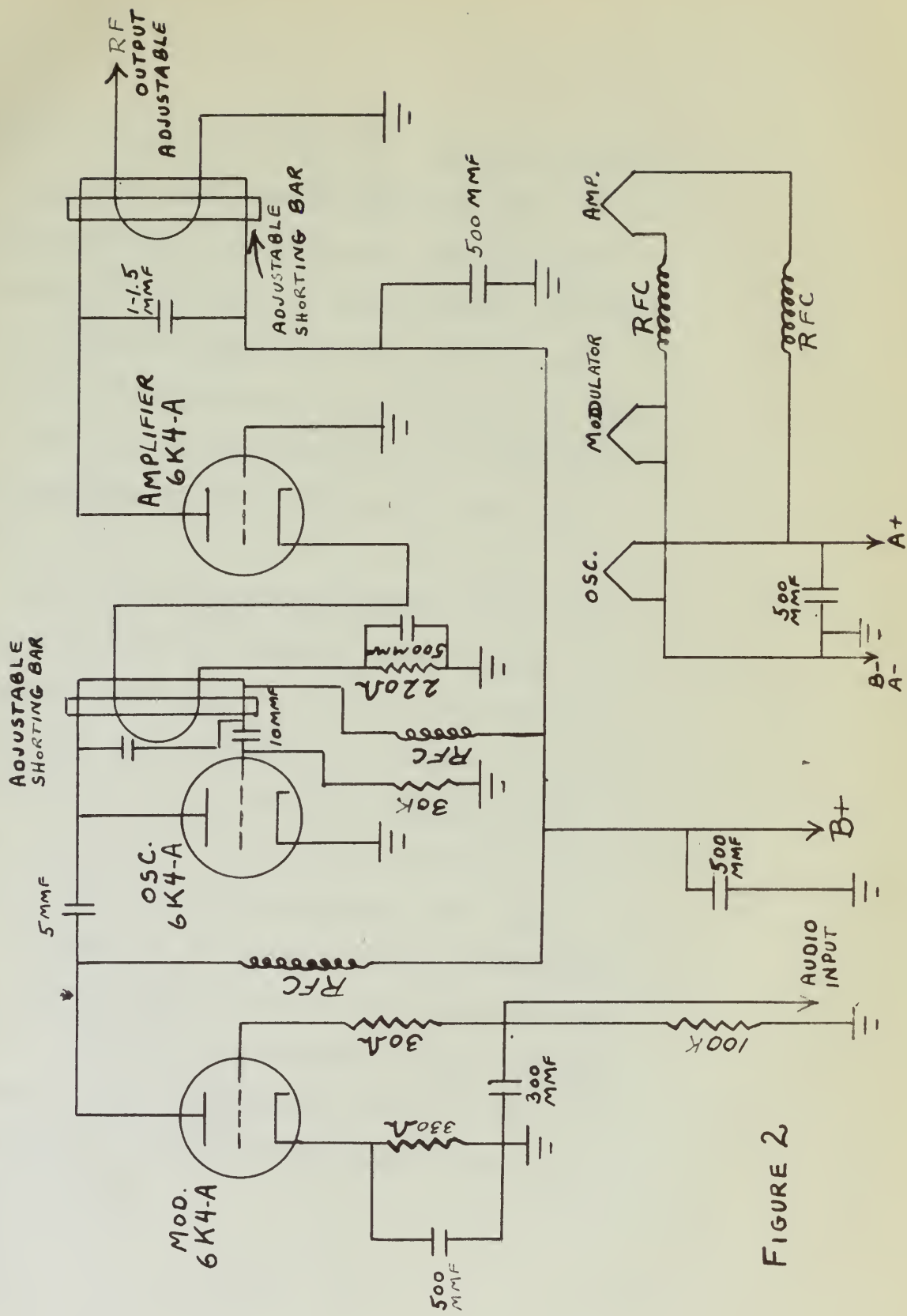


FIGURE 2



various stages, use leads to tubes as short as possible, and observe strictly all ordinary precautions to eliminate stray capacitances. This procedure would permit the testing of only one amplifier tube at a time. It would also be necessary to solder the leads of each tube in place for test, as there are no base pins or tube sockets for this type tube.

In view of the above stated conditions, and because it was desired to run normal load and particularly overload tests on as many tubes as possible, a simulator circuit using low frequency input was decided upon. The advantages of such a circuit from the testing point of view are many: a) Use of shielding in the chassis is not necessary. b) Several tubes can be tested simultaneously. c) Tubes can be mounted in tube socket adapters which are easily removable and in which tubes can be quickly inserted without soldering.



various sections, and leads to failure as shown  
 as possible, and observe especially all ordin-  
 any procedure to eliminate every imper-  
 tances. This procedure would require the remov-  
 ing of only one amplifier tube at a time.  
 It would also be necessary to replace the loads  
 of each tube in place for test, as shown and  
 no base pins or other sockets for this type  
 tube.

In view of the above stated conditions,

and because it was desired to run normal  
 load and particularly overload tests on the  
 many tubes as possible, a amplifier circuit  
 using low frequency input was decided upon.  
 The arrangement of each circuit from the  
 design point of view are many: a) Use  
 of shielding in the chassis is not necessary.  
 b) Several tubes can be tested simultaneously.  
 c) Tubes can be mounted in any order.  
 d) Amplifiers which are easily removable and in  
 which tubes can be easily inserted without  
 soldering.

The simulator circuit used is believed to be as close an approximation to the actual circuit as can be had using low frequency. The power outputs of the tubes in the simulator circuit can be adjusted to values reasonably close to the output obtained on test of the transmitter, depending on the uniformity of the ten tubes being tested.

Admittedly the simulator circuit is an alternative method of testing because it is generally accepted that the only real test of how a particular tube will perform in a particular circuit is its performance in that circuit. When the time requirements for testing in the actual circuit are considered, however, it is apparent that if more than a "handful" of tubes are to be tested singly an enormous amount of time would be required. The nine twenty hour tests described below would have required 1800 hours running time had the tubes been tested singly.

[illegible]



The circuit used to simulate the operation of the amplifier in the VHF Transmitter is shown in Figure 3. Originally a signal input frequency of 60 cycles per second was to be used. The impedance of the test circuit was so low, however, that a capacitor of approximately 100 mfd. would have been required across the power supply output to make the impedance of this capacitor small compared to the test circuit impedance. A signal frequency of 1000 cycles per second was therefore used, which was amplified before being applied to the test circuit.

As will be seen from the circuit diagram, the ten tubes to be tested were connected in parallel as separate amplifier tubes using common plate supply voltage and input signal sources. The cathode resistors were made 220 ohms, the same value used in the original circuit. The by-pass capacitors across the cathode resistors were made 50 mfd. to assure adequate by-passing of alter-



The circuit used to simulate the operation of the amplifier in the VIT Transmitter is shown in Figure 2. Originally a signal input frequency of 10 cycles per second was used. The impedance of the test circuit was so low, however, that a resistor of approximately 100 ohms would have been required across the power supply output to make the impedance of this resistor small compared to the test circuit impedance. A signal frequency of 1000 cycles per second was therefore used, which was amplified and then being applied to the test circuit. As will be seen from the circuit diagram, the test circuit is a parallel combination of a parallel resonant circuit and a series resonant circuit. The output transformer was made 250 ohms, the input being in the original circuit. The input impedance across the output resistance was 10 ohms, to ensure adequate impedance at input.

nating current at low frequency. The value of the load resistors was chosen as 3000 ohms to be of the same order of magnitude as the plate resistance of the tubes, which is listed as 3640 ohms for the 6K4-A Tube at 100 volts plate voltage and -2 volts grid bias.

It will be seen from the circuit diagram that the cathodes of the tubes being tested were not grounded, but were connected to the minus side of the plate power supply. The signal voltage at 1000 cycles per second was applied at the same point as the minus side of the power supply. This connection makes the minus side of the power supply above ground potential by the amount of the signal voltage; but in view of the small value of signal voltage used (6.2 volts r.m.s. maximum), this is of no consequence.

The first tests were of twenty hours duration. Twenty hours intermittent operation was

existing current in the transformer. The value  
 of the load resistance was chosen as 2000  
 ohms so as to be in the same order of magnitude  
 as the plate resistance of the tubes, which  
 is listed as 2000 ohms for the 6X4 tube  
 as 100 volts plate voltage and -1 volt grid  
 bias.  
 It will be seen from the above that  
 from that the impedance of the power supply  
 needed was not excessive, but was connected  
 to the same side of the plate power supply.  
 The signal voltage at 1000 cycles was around  
 one applied to the same point as the signal  
 side of the power supply. This connection  
 makes the same side of the power supply  
 above ground potential by the amount of the  
 signal voltage; but in view of the small  
 value of signal voltage used (0.1 volt r.m.s.)  
 maximum, this is of no consequence.  
 The first series was of twenty four tubes  
 plus. Twenty more independent operation was  
 made.

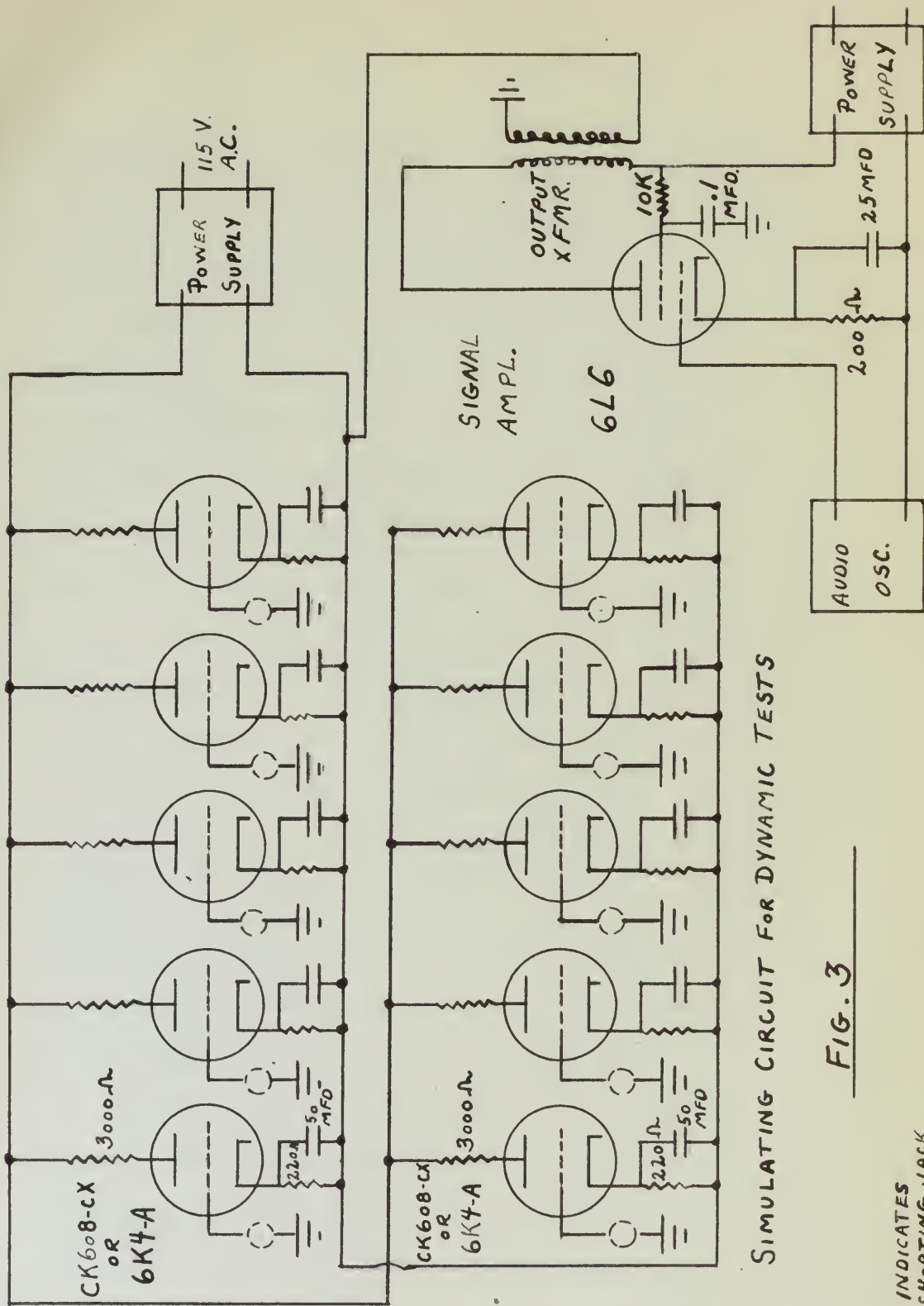


FIG. 3

SIMULATING CIRCUIT FOR DYNAMIC TESTS





considered, by Applied Physics Laboratory, to be satisfactory life for the transmitter in which the tubes are used.

Measurements were made in the following manner: a) Plate supply voltage was measured by a voltmeter on the power supply which was corrected by comparison with the reading of a Weston 1000 ohms per volt laboratory type meter placed across the output terminals of the power supply. b) Total plate current was measured by a D.C. milliammeter in the output circuit of the plate power supply. c) Grid current was measured by a D.C. milliammeter of 0 - 10 m.a. range which was placed in the grid circuit of each tube successively by means of a phone plug inserted in a shorting jack. This meter was shunted by a 5 mfd. capacitor. d) Output power was measured by means of Cathode Ray Oscillograph. The vertical deflection plates of the oscilloscope were connected directly from the positive side of the plate power supply to

considered, by Applied Physics Laboratory, to be satisfactory life for the treatment in which the tubes are used.

Measurements were made in the following manner: a) Glass supply voltage was measured by a voltmeter on the power supply which was corrected by comparison with the reading of a Weston 1000 volt per volt laboratory type meter placed across the output terminals of the power supply. b) Total plate current was measured by a 0.01 milliammeter in the output circuit of the glass power supply. c) Grid current was measured by a 0.01 milliammeter at  $0 - 10$  m.a. range which was placed in the grid circuit of each tube and connected by means of a phone plug inserted in a shorting jack. This meter was shunted by a 5 mfd. capacitor. d) Output power was measured by means of a radio frequency probe. The vertical deflection plates of the oscilloscope were connected directly from the positive side of the power supply to

the plate of the tube whose power was being measured. This connection gave a trace on the oscilloscope of the voltage existing across the load resistor of the tube. This voltage trace was plotted on cross section paper and from the plot the power was calculated. A sample plot is given as Plate VIII and a sample power calculation from this plot is given in Table XI of Appendix I.

Plates VIII - A, and VIII - B are plots of the grid and plate voltage traces of the Manufacturer "S" and Manufacturer "R" Tubes respectively. These plots were made for the same plate supply and signal voltages on each tube. They represent typical operation of the tubes in the simulator.

Plate VIII - C is a plot of grid bias voltage versus plate current for tubes 5B-27 and RB-12 at  $E_{plate} = 127, 100, 60$  volts. The dynamic operation lines for each tube are drawn on this plot for conditions of operation shown in Plates VIII A and B.



the plate of the tube whose power was being measured. This connection gave a view on the oscillations of the voltage existing across the load resistor of the tube. This voltage trace was plotted on square reaction paper and from this plot the power was calculated. A sample plot is given in Figure VIII and a sample power calculation from this plot is given in Table XI of Appendix I.

Plots VIII - 4, and VIII - 5 are plots of the grid and plate voltage traces of the "6" and "6AL5" tubes respectively. These plots were made for the same plate supply and signal voltages as were made. They represent typical operation of the tube in the simulator.

Plot VIII - 6 is a plot of grid plate voltage versus plate current for tubes 6-25 and 6-26 at 125, 100, and 50 volts. The dynamic operation lines for each tube are drawn on this plot for comparison of operation shown in Figure VIII 1 and 2.

# OUTPUT VOLTAGE TRACE ON C.R.O. TUBE

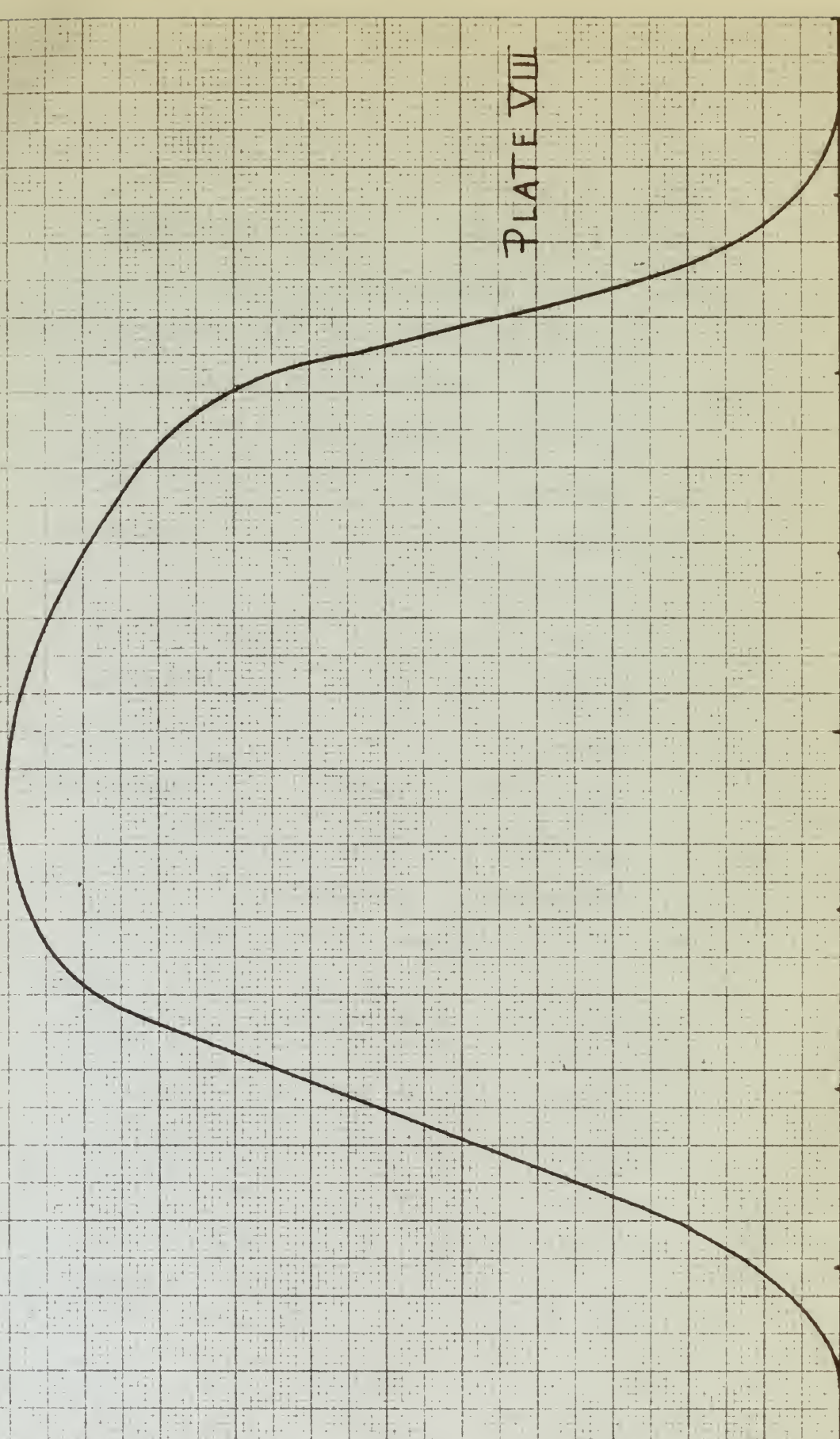
Small Divisions  
ON OSCILLOSCOPE

22  
21  
20  
19  
18  
17  
16  
15  
14  
13  
12  
11  
10  
9  
8  
7  
6  
5  
4  
3  
2  
1  
0

PLATE VIII

ELECTRICAL DEGREES

45° 90° 135° 180° 225° 270° 315° 360°







Plates VIII D and E are predicted plate voltage curves using the dynamic characteristics of Plate VIII C and the grid voltage curves of Plates VIII A and B. The actual curves obtained are plotted on the same sheet. Dashed portions of each curve are the extrapolated portions. The large difference between the curves at low values of plate voltage is caused by the fact that the grid is positive in this region and no data is available from curves of Plate VIII C on plate current for positive grid voltage.

The oscilloscope calibration of 4.9 volts per small scale division (49 volts per inch deflection) was obtained in the following manner: a) A D.C. voltage of known value was placed directly on the vertical deflection plates of the oscilloscope, (Dumont Type 208-B Cathode Ray Oscillograph). The deflection was found to be 10 small divisions (1 inch) per 49 volts D.C. b) An A.C. Voltage from an audio oscillator which



Planes VII B and C are provided with  
 surface curves under the dynamic characteristics  
 of Plane VII B and the side surface  
 curves of Plane VII A are 0. The actual  
 curves obtained are plotted on the same  
 sheet. Dashed portions of each curve are the  
 extrapolated portions. The large difference  
 between the curves at low values of plane  
 velocity is caused by the fact that the value  
 is positive in this region and no data is  
 available from curves of Plane VII B or  
 from curves for positive side velocity.  
 The coefficient of variation of 4.4  
 with low small angle velocity (as with  
 low side deflection) was obtained in the  
 following manner: a) A 1.4 velocity of  
 known value was placed directly on the velocity  
 of deflection plane in the coefficient  
 (known Type 104-5 velocity by coefficient).  
 The deflection was found to be 10 small  
 distance (1 inch) per 100 ft. b) A  
 1.4 velocity from an angle coefficient which

measured 15 volts r.m.s. was placed on the vertical deflection plates after the D.C. signal was removed. The deflection for this signal was 9 small divisions peak to peak, or 4.5 divisions peak value. Peak value of 15 volt r.m.s. signal  $= 15 \times \sqrt{2} = 21.2$  volts

$$\frac{21.2 \text{ volts}}{4.5 \text{ divisions}} = 4.7 \text{ volts/division}$$

It was decided that 4.9 volts / division was a sufficiently accurate value and this value was used.

#### Actual Procedure Used for Tests

The procedure of testing in the simulating circuit shown in Figure 3 was as follows:

- a) Ten tubes were tested simultaneously (unless there were not ten good tubes in one lot).
- b) Plate supply voltage was adjusted whenever it was observed to have drifted from the desired value for the particular test. The plate voltage used for each test was determined by the "cut and try" method to obtain the power output desired with a reasonable value of signal voltage applied. The power output

measured 15 volts across was placed on the  
 vertical deflection plates after the P.C.  
 signal was removed. The deflection for this  
 signal was a small distance back to peak, or  
 4.5 divisions peak value. Peak value of 18  
 volts was obtained as  $18 \times \sqrt{2} \approx 25.5$  volts  
 $\frac{25.5 \text{ volts}}{4.5 \text{ divisions}} = 5.7 \text{ volts/division}$   
 It was decided that 4.5 volts / division  
 was a sufficiently accurate value and this value  
 was used.

Animal Procedure Used for Tests

The procedure of testing in the animal  
 is circuit shown in Figure 3 was as follows:  
 a) Ten tubes were tested simultaneously and  
 four there were not run each tube in one test.  
 b) Plate supply voltage was adjusted whenever  
 it was observed to have drifted from the de-  
 sired value for the particular test. The plate  
 voltage used for each test was recorded in  
 the "test and 175" column on opposite the lower  
 subject column with a reasonable value of  
 signal voltage applied. The power output



TUBE SB-27

$E_b = 127 \text{ V.}$

$E_{\text{signal}} = 4.0 \text{ V. (r.m.s.)}$

$E_c \text{ (no signal)} = -2.6 \text{ V.}$

$E_c \text{ (signal on)} = -3.2 \text{ V.}$

$I_{\text{PLATE}} \text{ (no signal)} = 10 \text{ ma}$

$I_{\text{PLATE}} \text{ (signal on)} = 11.5 \text{ ma}$

$I_{\text{gr10}} = 0.6 \text{ m.a.}$

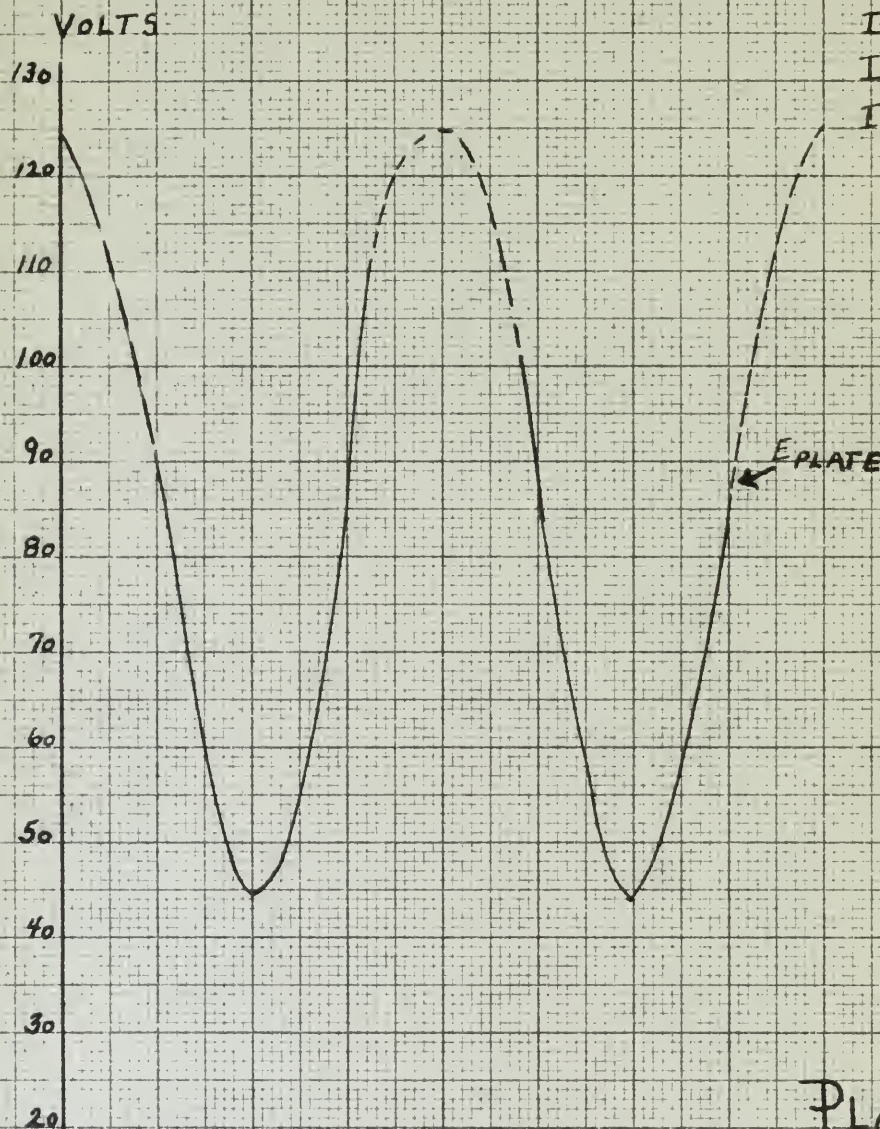
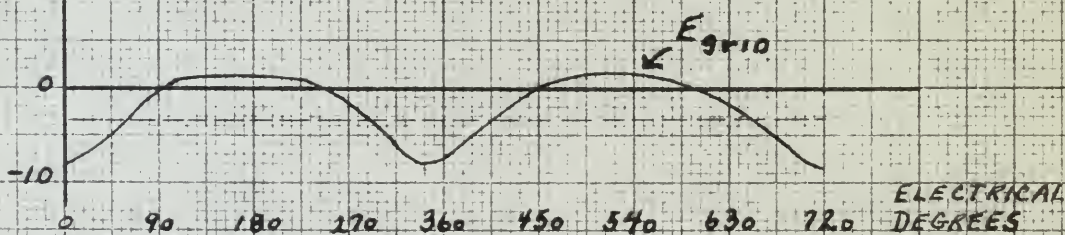


PLATE VIII - A







# TUBE RB-12

$$E_b = 127 \text{ V.}$$

$$E_{\text{signal}} = 4.0 \text{ V. (r.m.s.)}$$

$$E_{\text{grid (no signal)}} = -1.84 \text{ V.}$$

$$E_{\text{grid (signal on)}} = -2.2 \text{ V.}$$

$$I_{\text{PLATE (no signal)}} = 7.5 \text{ m.a.}$$

$$I_{\text{PLATE (signal on)}} = 9.5 \text{ m.a.}$$

$$I_{\text{grid}} = 0.72 \text{ m.a.}$$

VOLTS

130

120

110

100

90

80

70

60

50

40

30

20

10

0

-10

$E_{\text{PLATE}}$

PLATE VIII - B

$E_{\text{grid}}$

ELECTRICAL  
DEGREES

0

90

180

270

360

450

540

630

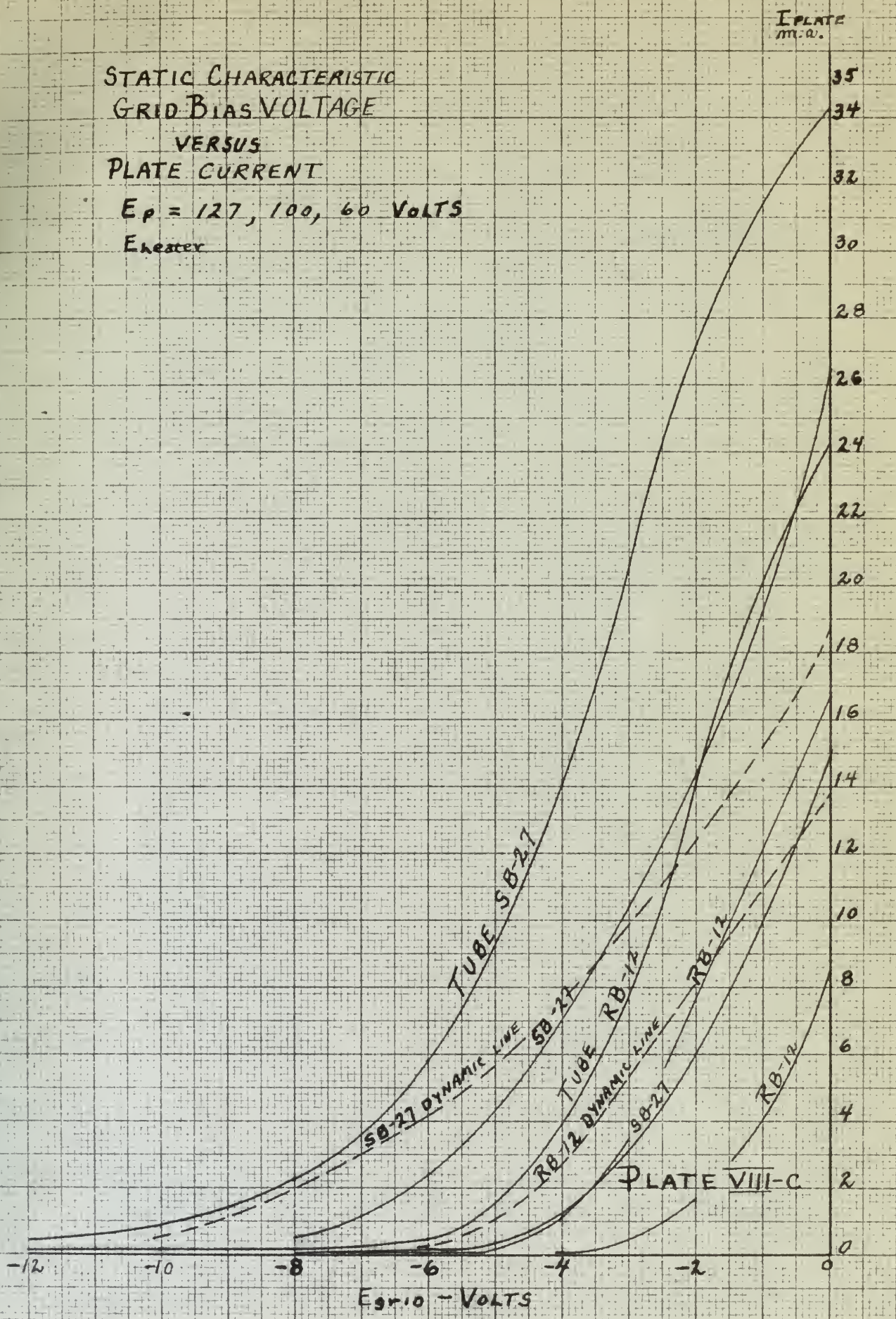
720





STATIC CHARACTERISTIC  
GRID BIAS VOLTAGE  
VERSUS  
PLATE CURRENT

$E_p = 127, 100, 60 \text{ VOLTS}$   
 $E_{\text{heater}}$

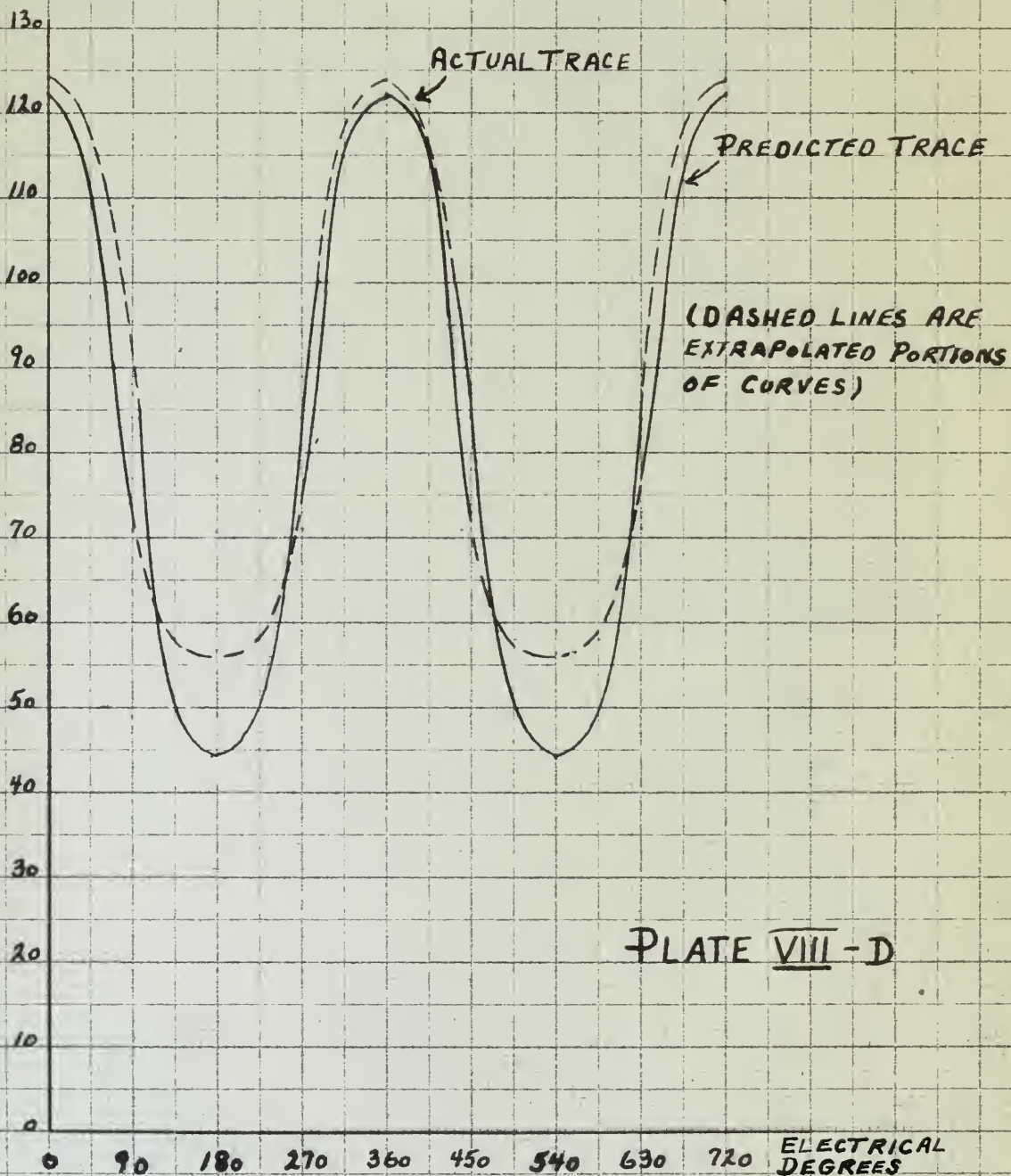






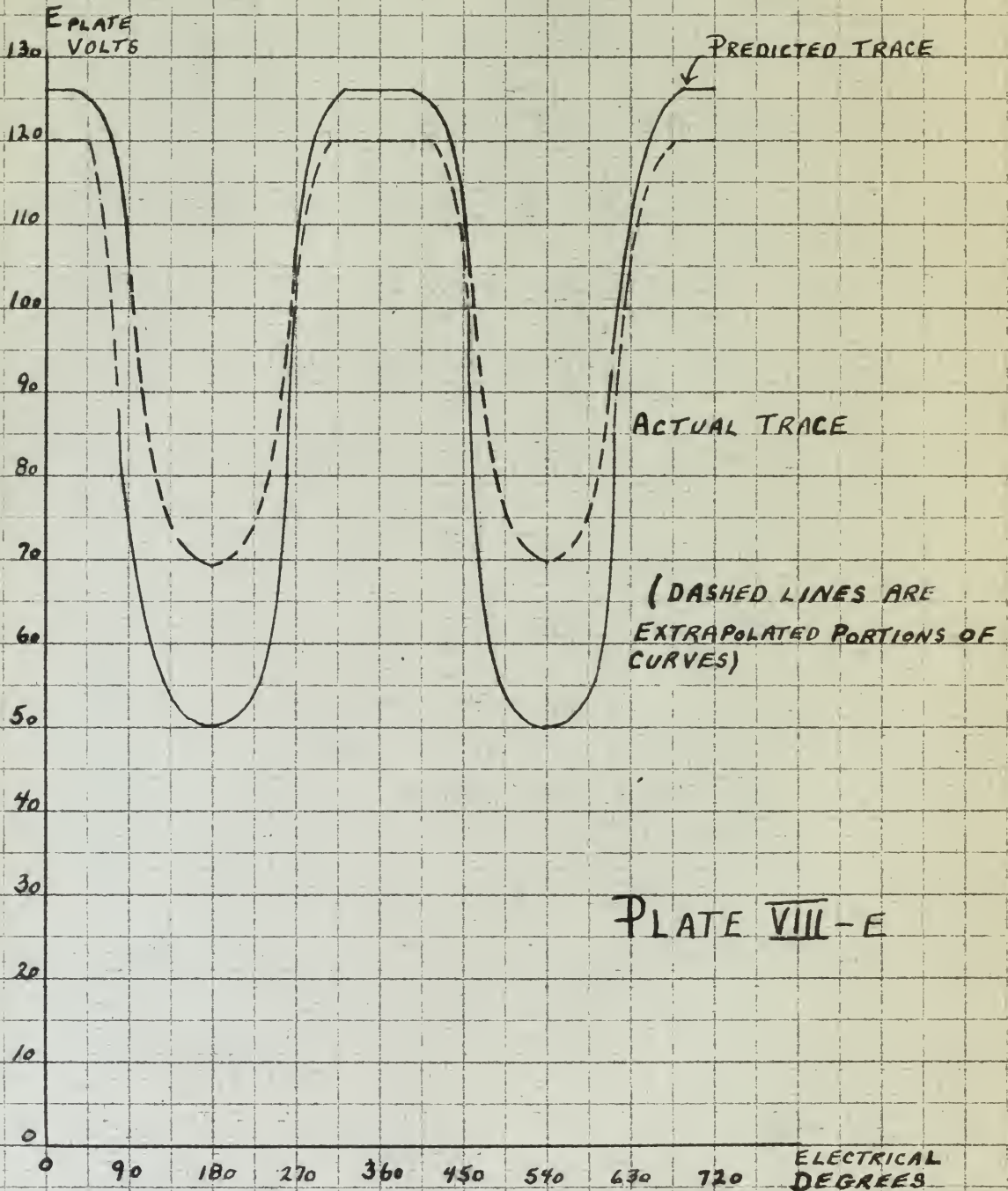
E<sub>PLATE</sub>  
VOLTS

TUBE SB-27





TUBE RB-12







was computed from direct observation of the output voltage wave shape on the oscilloscope, as previously mentioned. Since the wave shape was made up of plate and signal voltage components essentially, and since a grid current not in excess of 5 m.a. per tube was desired, it was not difficult to obtain a combination of signal and plate voltage which gave the desired power output. On the first test run with Manufacturer "S" Tubes the plate supply voltage was set at 130 V. because this was the value given for the transmitter amplifier tube. The signal voltage was then adjusted to give an output approximately equal to the average value obtained on tests of the transmitter. In subsequent tests the plate voltage and signal voltage were increased to obtain the increased power desired.

c) The signal voltage was set initially and after each shut down. The shut downs were at approximately 30 minute intervals throughout the 20 hour tests.

was recorded from direct observation of the  
 output voltage wave shape on the oscilloscope,  
 as previously mentioned. Since the wave shape  
 was made up of glass and signal voltage some  
 points essentially, and since a rise current  
 not in excess of 5 m.a. per inch was de-  
 sired, it was difficult to obtain a com-  
 position of signal and glass voltage which  
 gave the desired power output. On the first  
 test run with harmonics at 100 V. the  
 glass output voltage was set at 100 V. be-  
 cause this was the value given for the trans-  
 mitter amplifier tube. The signal voltage  
 was then adjusted to give an output approxi-  
 mately equal to the average value obtained on  
 tests of the transmitter. In subsequent tests  
 the glass voltage and signal voltage were in-  
 creased to obtain the increased power desired.  
 c) The signal voltage was set initially and  
 after each test run. The test design was an  
 approximately 30 minute interval throughout  
 the 30 hour tests.

- d) The total plate supply current was recorded before each shutdown with signal voltage on and after each shutdown before the signal voltage was turned on again.
- e) The grid current was recorded and averaged approximately each hour during the 20 hour tests.
- f) On the first few tests, before it was known how long the tubes would last, static tests were run after about 10 hours operation. This was discontinued when it was seen to be no longer necessary, and only one static test at the end of 20 hours of operation was made.
- g) The shutdowns consisted of turning off all voltages on the tubes, allowing heater filaments to lose their visible glow and then again applying tube heater, plate, and signal voltages in that order.
- h) Wave shape was observed several times during each test on two or three tubes for the first tests and later on all tubes.



4) The total plate supply current was now  
condensed before each shutdown with slight delay  
now on and after each shutdown before the sig-  
nal voltage was formed on signal.

5) The grid current was recorded and averaged  
approximately each hour during the 50 hour  
tests.

6) On the first few tests, before it was  
known how long the tubes would last, single  
tests were run after about 10 hours operation.  
This was discontinued when it was seen to be  
no longer necessary, and only one test was  
at the end of 50 hours of operation was made.

7) The shutdowns consisted of turning off  
all voltages on the tubes, allowing heater  
filaments to cool their plate glow and then  
again applying the heater, plate, and signal  
voltages in that order.

8) Tube shape was observed several times dur-  
ing each test on two or three tubes for the  
first tests and later on all tubes.

### Description of Individual Tests

Test 1 - 20 hours. Average Power  $\pm$  0.8 watt/tube. Tubes - 6A1-6A10. (These tubes had been operated under varying conditions for several hours prior to test in setting up the test circuit).

Tube 6A-10 failed after 30 minutes operation. The failure was noted by the sharp drop in plate supply voltage, and a sharp rise in total plate current. When this tube was placed in the tester, its heater circuit drew only about one third normal current, plate voltage would not build up, plate current rose quickly to many times its normal value as plate voltage was applied and its indicated transconductance was almost zero.

### Summary of data taken in connection with test:

	Before Test	After Test	Change
Average Plate Current	10.3 m.a.	8.9 m.a.	-1.4 m.a.

Description of Individual Tests

Test 1 - No motor. Average power  $\approx 0.5$

where power =  $\frac{1}{2} I^2 R$ . (These tests had been repeated many times for several hours prior to test 1 on the test stand).

Test 2-10 tests after 30 minutes operation. The results were noted by the sharp drop in plate supply voltage, and a sharp rise in total plate current. When this time was placed in the center, the meter circuit then only showed the slight current, plate voltage would not build up, plate current rose quickly to many times the normal value as plate voltage was applied and the indicated phenomenon was almost zero.

Summary of data taken in connection with test

Before test after test

Average plate current	10.0 m.a.	1.5 m.a.	1.0 m.a.
Before test	10.0 m.a.	1.5 m.a.	1.0 m.a.
After test	10.0 m.a.	1.5 m.a.	1.0 m.a.



<u>Before Test</u>	<u>After Test</u>	<u>Change</u>
Average Trans-conductance 3460 micromhos	3320 micromhos	-140

Maximum Change in Plate current due to test	-1.6 m.a.
---	-----------

Maximum Change in Transconductance due to test	-280 micromhos
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Average grid current during test: 0.28 m.a.

Plate Supply Voltage 145 V. for 10 hours; 130 V. for 10 hours; Average Signal voltage 4.83 V. (r.m.s.).

Remarks: Failure of Tube 3A-10 attributed to use prior to this test.

Test 2 - 20 hours. Average Power  $\pm$  0.81 watt/tube. Tubes - 3B1-3B10. No failures occurred during test.

Summary of data taken in connection with test:

	<u>Before Test</u>	<u>After Test</u>	<u>Change</u>
Average Plate Current	15.5 m.a.	12.0 m.a.	-3.5
Average Trans-conductance	4295 micromhos	3885 micromhos	-408



Initial Test      Station 2000      Class

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Maximum Change in transconductance due  
to test -860

Average grid current during test 0.255 m.a.

Plate Supply Voltage 130 V. Average Signal  
Voltage 4.27 V. (r.m.s.)

Test 3 - 20 hours. Average Power  $\pm$  1.12  
watts/tube. Tubes 5B11-5B18, 5B20, 5B21.

No failures occurred during test.

Summary of data taken in connection with test:

	<u>Before Test</u>	<u>After Test</u>	<u>Change</u>
Average Plate Current	16.1 m.a.	10.4 m.a.	-5.7
Average Trans- conductance	4371 micromhos	3053 mi- cromhos	-1318

Maximum Change in Plate Current due to test  
-8.9 m.a.

Maximum Change in Transconductance due to  
test -1800 micromhos

Average grid current during test 0.145 m.a.

Plate supply voltage 165,170,180 V. Aver-  
age Signal voltage 6.04V (r.m.s.)

Maximum Charge in Transmission Line

on 1000 - 5000

average this current during peak 0.250 m.a.

Line Supply Voltage 120 V. Average (line)

Voltage 4.2V (7.0m.a.)

Test 2 - 20 hours. Average Power = 1.12

Watts. Total 1000-1000, 1000, 1000.

On failure occurred during test.

Summary of data taken in connection with test:

Before Test After Test Change

Current	10.1 m.a.	10.4 m.a.	+0.3
---------	-----------	-----------	------

Average Power	4371 m.watts	4381 m.w.	+10
---------------	--------------	-----------	-----

Maximum Charge in Line Current was 0.250

0.250 m.a.

Maximum Charge in Transmission Line was 0.250

Peak - 1000 m.watts

Average and current during peak 0.100 m.a.

Line Supply Voltage 120, 120 V. 1000-

and Normal Voltage 1.00V (7.0m.a.)

Test 4 - 20 hours. Average Power  $\pm$  1.6 watts/tube. Tubes SC-2-SC7, SC9, SC10, SC11, SC13. No failures occurred during test. Tube SC1 failed to operate when test was started. This tube tested perfectly on static test and had not been used between static and dynamic tests.

Summary of data taken in connection with test:

	<u>Before Test</u>	<u>After Test</u>	<u>Change</u>
Average Plate Current	11.7 m.a.	6.5 m.a.	-5.2
Average Transconductance	3899 micromhos	2447 micromhos	-1452
Maximum Change in Plate Current due to test			
			-7.5 m.a.
Maximum Change in Transconductance due to test			
			-1980 micromhos
Average grid current during test 0.189 m.a.			
Plate supply voltage 200 V. Average Signal Voltage 6.24 V. (r.m.s.)			



Test 4 - 30 hours. Sample time 1.5  
msec/cycle. Time 0.5-1.0, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, 10.5, 11.0, 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 15.5, 16.0, 16.5, 17.0, 17.5, 18.0, 18.5, 19.0, 19.5, 20.0, 20.5, 21.0, 21.5, 22.0, 22.5, 23.0, 23.5, 24.0, 24.5, 25.0, 25.5, 26.0, 26.5, 27.0, 27.5, 28.0, 28.5, 29.0, 29.5, 30.0, 30.5, 31.0, 31.5, 32.0, 32.5, 33.0, 33.5, 34.0, 34.5, 35.0, 35.5, 36.0, 36.5, 37.0, 37.5, 38.0, 38.5, 39.0, 39.5, 40.0, 40.5, 41.0, 41.5, 42.0, 42.5, 43.0, 43.5, 44.0, 44.5, 45.0, 45.5, 46.0, 46.5, 47.0, 47.5, 48.0, 48.5, 49.0, 49.5, 50.0, 50.5, 51.0, 51.5, 52.0, 52.5, 53.0, 53.5, 54.0, 54.5, 55.0, 55.5, 56.0, 56.5, 57.0, 57.5, 58.0, 58.5, 59.0, 59.5, 60.0, 60.5, 61.0, 61.5, 62.0, 62.5, 63.0, 63.5, 64.0, 64.5, 65.0, 65.5, 66.0, 66.5, 67.0, 67.5, 68.0, 68.5, 69.0, 69.5, 70.0, 70.5, 71.0, 71.5, 72.0, 72.5, 73.0, 73.5, 74.0, 74.5, 75.0, 75.5, 76.0, 76.5, 77.0, 77.5, 78.0, 78.5, 79.0, 79.5, 80.0, 80.5, 81.0, 81.5, 82.0, 82.5, 83.0, 83.5, 84.0, 84.5, 85.0, 85.5, 86.0, 86.5, 87.0, 87.5, 88.0, 88.5, 89.0, 89.5, 90.0, 90.5, 91.0, 91.5, 92.0, 92.5, 93.0, 93.5, 94.0, 94.5, 95.0, 95.5, 96.0, 96.5, 97.0, 97.5, 98.0, 98.5, 99.0, 99.5, 100.0, 100.5, 101.0, 101.5, 102.0, 102.5, 103.0, 103.5, 104.0, 104.5, 105.0, 105.5, 106.0, 106.5, 107.0, 107.5, 108.0, 108.5, 109.0, 109.5, 110.0, 110.5, 111.0, 111.5, 112.0, 112.5, 113.0, 113.5, 114.0, 114.5, 115.0, 115.5, 116.0, 116.5, 117.0, 117.5, 118.0, 118.5, 119.0, 119.5, 120.0, 120.5, 121.0, 121.5, 122.0, 122.5, 123.0, 123.5, 124.0, 124.5, 125.0, 125.5, 126.0, 126.5, 127.0, 127.5, 128.0, 128.5, 129.0, 129.5, 130.0, 130.5, 131.0, 131.5, 132.0, 132.5, 133.0, 133.5, 134.0, 134.5, 135.0, 135.5, 136.0, 136.5, 137.0, 137.5, 138.0, 138.5, 139.0, 139.5, 140.0, 140.5, 141.0, 141.5, 142.0, 142.5, 143.0, 143.5, 144.0, 144.5, 145.0, 145.5, 146.0, 146.5, 147.0, 147.5, 148.0, 148.5, 149.0, 149.5, 150.0, 150.5, 151.0, 151.5, 152.0, 152.5, 153.0, 153.5, 154.0, 154.5, 155.0, 155.5, 156.0, 156.5, 157.0, 157.5, 158.0, 158.5, 159.0, 159.5, 160.0, 160.5, 161.0, 161.5, 162.0, 162.5, 163.0, 163.5, 164.0, 164.5, 165.0, 165.5, 166.0, 166.5, 167.0, 167.5, 168.0, 168.5, 169.0, 169.5, 170.0, 170.5, 171.0, 171.5, 172.0, 172.5, 173.0, 173.5, 174.0, 174.5, 175.0, 175.5, 176.0, 176.5, 177.0, 177.5, 178.0, 178.5, 179.0, 179.5, 180.0, 180.5, 181.0, 181.5, 182.0, 182.5, 183.0, 183.5, 184.0, 184.5, 185.0, 185.5, 186.0, 186.5, 187.0, 187.5, 188.0, 188.5, 189.0, 189.5, 190.0, 190.5, 191.0, 191.5, 192.0, 192.5, 193.0, 193.5, 194.0, 194.5, 195.0, 195.5, 196.0, 196.5, 197.0, 197.5, 198.0, 198.5, 199.0, 199.5, 200.0, 200.5, 201.0, 201.5, 202.0, 202.5, 203.0, 203.5, 204.0, 204.5, 205.0, 205.5, 206.0, 206.5, 207.0, 207.5, 208.0, 208.5, 209.0, 209.5, 210.0, 210.5, 211.0, 211.5, 212.0, 212.5, 213.0, 213.5, 214.0, 214.5, 215.0, 215.5, 216.0, 216.5, 217.0, 217.5, 218.0, 218.5, 219.0, 219.5, 220.0, 220.5, 221.0, 221.5, 222.0, 222.5, 223.0, 223.5, 224.0, 224.5, 225.0, 225.5, 226.0, 226.5, 227.0, 227.5, 228.0, 228.5, 229.0, 229.5, 230.0, 230.5, 231.0, 231.5, 232.0, 232.5, 233.0, 233.5, 234.0, 234.5, 235.0, 235.5, 236.0, 236.5, 237.0, 237.5, 238.0, 238.5, 239.0, 239.5, 240.0, 240.5, 241.0, 241.5, 242.0, 242.5, 243.0, 243.5, 244.0, 244.5, 245.0, 245.5, 246.0, 246.5, 247.0, 247.5, 248.0, 248.5, 249.0, 249.5, 250.0, 250.5, 251.0, 251.5, 252.0, 252.5, 253.0, 253.5, 254.0, 254.5, 255.0, 255.5, 256.0, 256.5, 257.0, 257.5, 258.0, 258.5, 259.0, 259.5, 260.0, 260.5, 261.0, 261.5, 262.0, 262.5, 263.0, 263.5, 264.0, 264.5, 265.0, 265.5, 266.0, 266.5, 267.0, 267.5, 268.0, 268.5, 269.0, 269.5, 270.0, 270.5, 271.0, 271.5, 272.0, 272.5, 273.0, 273.5, 274.0, 274.5, 275.0, 275.5, 276.0, 276.5, 277.0, 277.5, 278.0, 278.5, 279.0, 279.5, 280.0, 280.5, 281.0, 281.5, 282.0, 282.5, 283.0, 283.5, 284.0, 284.5, 285.0, 285.5, 286.0, 286.5, 287.0, 287.5, 288.0, 288.5, 289.0, 289.5, 290.0, 290.5, 291.0, 291.5, 292.0, 292.5, 293.0, 293.5, 294.0, 294.5, 295.0, 295.5, 296.0, 296.5, 297.0, 297.5, 298.0, 298.5, 299.0, 299.5, 300.0, 300.5, 301.0, 301.5, 302.0, 302.5, 303.0, 303.5, 304.0, 304.5, 305.0, 305.5, 306.0,

[illegible]

Test 5 - 20 hours. Average Power  $\pm$  1.6 watts/tube. Tubes 8A11-8A20. No failures occurred during test.

Summary of data taken in connection with test:

	<u>Before Test</u>	<u>After Test</u>	<u>Change</u>
Average Plate Current	10.9 m.a.	7.31 m.a.	-3.59
Average Transconductance	3572 micromhos	2624 micromhos	-948

Maximum Change in plate current due to test -6.2

Maximum Change in Transconductance due to test -1440 micromhos

Average grid current during test 0.258 m.a.

Plate Supply Voltage 200 V. Average Signal Voltage 6.02 V. (r.m.s.)

Test 6 - 20 hours. Average Power  $\pm$  0.60 watt/tube. Tubes 8A-1-8A6, 8A8, 8A-9, 8A10. No failures occurred during test.

Test 5 - 50 hours. Average Power  $\pm 1.5$

Notes: Power 1.5-2.0. No further

measured during test.

Summary of data taken in connection with test:

Notes: Test 5. After Test 5.

Notes: 1.5-2.0. 1.5-2.0. 1.5-2.0.

Notes: 1.5-2.0. 1.5-2.0. 1.5-2.0.

Notes: 1.5-2.0. 1.5-2.0. 1.5-2.0.

-1.5

Notes: 1.5-2.0. 1.5-2.0. 1.5-2.0.

Notes: 1.5-2.0. 1.5-2.0. 1.5-2.0.

Notes: 1.5-2.0. 1.5-2.0. 1.5-2.0.

Notes: 1.5-2.0. 1.5-2.0. 1.5-2.0.

Notes: 1.5-2.0. 1.5-2.0. 1.5-2.0.

Test 6 - 50 hours. Average Power  $\pm 0.50$

Notes: Power 1.5-2.0. 1.5-2.0. 1.5-2.0.

No further measured during test.

Notes: 1.5-2.0. 1.5-2.0. 1.5-2.0.

	<u>Before Test</u>	<u>After Test</u>	<u>Change</u>
Average Plate Current	11.7 m.a.	10.95 m.a.	-.75
Average Trans- conductance	4150 micromhos	3920 mi- cromhos	-230

Maximum Change in Plate Current due to test  
-2.2 m.a.

Maximum change in Transconductance due to  
test -530 micromhos

Average grid current during test 0.611 m.a.

Plate Supply Voltage 135W. Average Signal  
Voltage 4.87 V. (r.m.s.)

Remarks: On some tubes the output wave  
showed distortion in addition to the usual  
flat portions. The tubes in which this dis-  
tortion appeared however, were no different  
in static characteristics from the other  
tubes.

Test 7 - 20 hours. Average Power  $\pm$  1.2  
watts/tube. Tubes RE1-RE10. No failures  
occurred during test.



Before Test    After Test    Change

Average Phase    11.7 m.s.    10.95 m.s.    -.75

Average Phase-  
Distance    4100 m.s.    3950 m.s.    -150

Maximum Change in Phase between two tests  
-1.5 m.s.

Maximum change in Phase between two tests  
-1.5 m.s.

Average and constant during test 0.411 m.s.  
Phase supply Voltage 110V. Average signal  
Voltage 4.8V (r.m.s.)

Remarks: On some tubes the output wave  
showed distortion in addition to the usual  
ring portion. The tubes in which this dis-  
tortion appeared however, were no different  
in basic characteristics from the other  
ones.

Less 10 hours. Average lower 1.5

Notes: Tubes 7B1-7B1C. No failures  
occurred during test.

Summary of data taken in connection with test:

	<u>Before Test</u>	<u>After Test</u>	<u>Change</u>
Average Plate Current	10.66 m.a.	11.16 m.a.	+0.50
Average Trans-conductance	3982	3863	-119
Maximum Change in Plate Current due to test			+2.7 m.a.

Maximum Change in Transconductance due to test -340 micromhos

Average grid current during test 0.288 m.a.

Plate Supply Voltage 200V. Average Signal Voltage 5.09 V. (r.m.s.)

Remarks: Output wave on some tubes showed considerable "jitter" in amplitude (see Photograph #3). The maximum amplitude of the wave was not clearly defined but covered three or four small divisions on the Cathode Ray Tube scale. The tubes in which this was observed showed no differences on static test from the other tubes.

Summary of data taken in connection with test:

Before Test After Test Change

Average Power 10.00 m.w. 11.12 m.w. 4.12

Average Trans- 2222 2222

Maximum Power in Test 11.12 m.w. 11.12 m.w.

4.12 m.w.

Maximum Change in Transconductance 4.12

Test 2222 m.w.

Average Pile current during test 0.2222 m.w.

Test Supply Voltage 2222 m.w.

Voltage 2222 V. (2222 V.)

Remarks: Output was on same tubes shown

maximum in "list" in section 1222

Photocell 2222. The maximum recorded at

the test was not clearly defined but 2222-

of time or test result 2222 of 2222

Maximum test time 2222. The tubes in which

this was observed showed no difference in

results from the other tubes.

Test 8 - 20 hours. Average Power  $\pm$  1.59 watts/tube. Tubes RC1-RC10. No failures occurred during test.

Summary of data taken in connection with test:

	<u>Before Test</u>	<u>After Test</u>	<u>Change</u>
Average Plate Current	8.86 m.a.	9.50 m.a.	+0.62
Average Transconductance	3626 mi-cromhos	3531 mi-cromhos	-95

Maximum Change in Plate current due to test  
+6.0 m.a.

Maximum Change in Transconductance due to test -800 micromhos

Average grid current during test 0.326 m.a.

Plate Supply Voltage 235 V. Average Signal Voltage 6.25 V. (r.m.s.)

Remarks: Same as for Test 7.

Test 9 - 20 hours. Average Power  $\pm$  1.49 watts/tube. Tubes RC11-RC20. No failures occurred during test.



Test 5 - 20 hours. Average Power = 1.40

Water/Air. Tubes 101-1012. No failures

occurred during test.

Summary of Data Taken in connection with Test 5

Water/Air. Tubes 101-1012. No failures

Water/Air. Tubes 101-1012. No failures

Water/Air. Tubes 101-1012. No failures

Water/Air. Tubes 101-1012. No failures

4.25 m.s.

Water/Air. Tubes 101-1012. No failures

4.25 m.s.

Water/Air. Tubes 101-1012. No failures

Water/Air. Tubes 101-1012. No failures

Water/Air. Tubes 101-1012. No failures

Water/Air. Tubes 101-1012. No failures

Test 6 - 20 hours. Average Power = 1.40

Water/Air. Tubes 101-1012. No failures

occurred during test.

Summary of data taken in connection with test:

	<u>Before Test</u>	<u>After Test</u>	<u>Change</u>
Average Plate Current	8.67 m.a.	8.35 m.a.	-0.32
Average Trans-conductance	3534 mi-cromhos	3437 mi-cromhos	-97

Maximum Change in Transconductance due to test -500 micromhos

Average grid current during test 0.838 m.a.

Plate Supply Voltage 235 V. Average Signal voltage 6.26 V. (r.m.s.)

A comparison of the changes of tube parameters with use can be quickly obtained by reference to the table below. The first test made on Manufacturer "S" Tubes has been omitted because of the use of these tubes prior to testing.

Summary of data taken in connection with test:

Before Test After Test Change

Average Water	5.67 m.m.	6.48 m.m.	-0.81
Corrected			
Average Water	5.67 m.m.	6.48 m.m.	-0.81
Conductance	285 m.m.	300 m.m.	-15
Resistance	350 ohms	333 ohms	17

Maximum change in resistance was 17

ohms - 500 ohms

Average rise occurred during test 0.81 m.m.

Water supply follows 500 m.m. average signal

Pointed out (7.4.4.)

A comparison of the signal of 500

ohms with the one for 500 ohms

by reference to the table below. The first

test made on temperature 500 ohms has been

omitted because of the use of these tubes

prior to test/4.

Manufacturer "S" Tubes

Test	P average tube(watts)	Williams Change in Av. Iplate	Microhm Change in Av. Rm	% change in Rm
2	0.81	-3.30	- 406	9.52
3	1.12	-5.70	-1316	30.15
4	1.60	-5.20	-1452	37.35
5	1.50	-3.59	- 948	26.55
Aver.	1.26	-4.94	-1081	25.9

Manufacturer "R" Tubes

6	0.60	-0.75	-230	5.55
7	1.20	+0.50	-119	2.98
8	1.59	+0.62	- 95	2.62
9	1.49	-0.32	- 97	2.75
Aver.	1.22	+0.012	-135.2	3.48

Photographs which follow are typical  
output voltage wave forms on the oscilloscope  
for different tubes.



For different cases.

output voltage wave forms in the oscillations

Photographs of the wave forms are typical

Case 1	1.25	40.00	-10.00	2.00
Case 2	1.50	40.00	-10.00	2.00
Case 3	1.75	40.00	-10.00	2.00
Case 4	2.00	40.00	-10.00	2.00
Case 5	2.25	40.00	-10.00	2.00

Table 1: Typical wave forms

Case 1	1.25	40.00	-10.00	2.00
Case 2	1.50	40.00	-10.00	2.00
Case 3	1.75	40.00	-10.00	2.00
Case 4	2.00	40.00	-10.00	2.00
Case 5	2.25	40.00	-10.00	2.00

Typical wave forms in the oscillations  
 (a) Typical wave forms in the oscillations  
 (b) Typical wave forms in the oscillations  
 (c) Typical wave forms in the oscillations  
 (d) Typical wave forms in the oscillations  
 (e) Typical wave forms in the oscillations

Table 2: Typical wave forms



Manufacturer "S" Tube  
Output Voltage Wave  
Photograph 1

உயர்நீதிமன்றம், சென்னை

Output Folded

THE UNIVERSITY OF CHICAGO

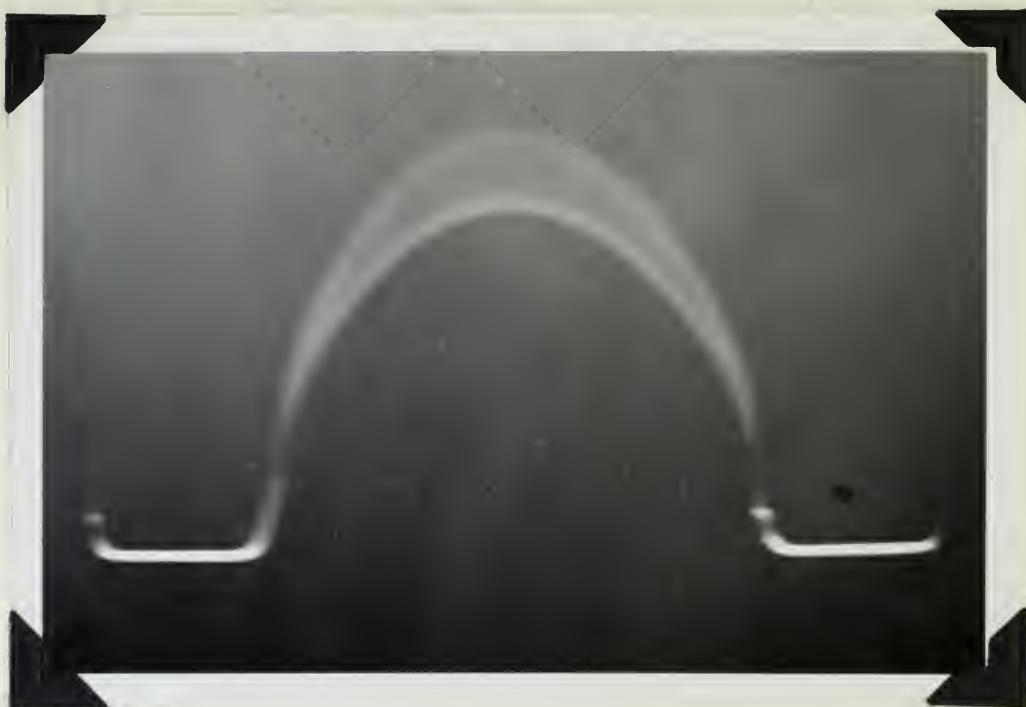


Manufacturer "R" Tube  
Output Voltage Wave  
Photograph 2





TRANSLATED BY THE  
LARRY VOLKMAN  
PHOTOGRAPHY 2



Manufacturer "R" Tube  
Output Voltage Wave, illus-  
trating "noise" or "jitter"  
appearing on some Manufacturer  
"R" Tubes - Photograph 3.



"R" tapes - Photograph 5.  
appearing on some knowledge  
creating "notes" or "R" tapes  
Oxford Police, 11/10/50  
Investigator "R" tapes

Upon completion of the nine tests described above, it was decided that sufficient data had been obtained on the short time capabilities of the tubes. Supplementary tests were run to determine how long tubes would operate before failing completely; or if this was not possible, due to excessive time requirements, what comparative changes in tube characteristics and power output would occur due to operation. Tests Four and Nine were continued with the same tubes operating at the same plate and signal voltages until each set of tubes had operated for 60 hours. The tubes were operated continuously for periods of about eight hours with no shutdowns until the 60 hours operation was completed. The following results were obtained from these tests:

- a) No failures occurred on either Manufacturer "S" or Manufacturer "R" Tubes.
- b) The total changes in parameters for the



Upon completion of the above tests, the  
 order above, it was decided that additional  
 tests had been obtained on the same time  
 capabilities of the tubes. Repetitive  
 tests were run to determine how long tubes  
 would operate before failing completely; or  
 if this was not possible, use an excessive  
 time requirement, what cooperative changes  
 in tube characteristics and power output  
 would occur due to operation. Tests four  
 and five were conducted with the same tubes  
 operation at the same place and signal with  
 after which each set of tubes had undergone for  
 50 hours. The tubes were operated normally  
 usually for periods of about eight hours with  
 an exception until the 50 hour operation  
 was completed. The following results were  
 obtained from these tests:

- a) No failure occurred at 50 hour mark.
- b) The total number of failures for the

60 hour tests were as tabulated below:

	Average $G_m$ after 60 hrs. before test	Average $G_m$	Average $\Delta G_m$	Average $\Delta I_{plate}$
Manufact- urer "S" Tubes SC2- 7,9,10,11, 13	2667	3899	-1232	-5.03
Manufact- urer "R" Tubes RC11 - 20	3528	3534	- 6	+0.40

$G_m$  in micromhos

$I_{plate}$  in milliamps

a) Tubes SC4 and RC13 respectively were the low tubes in power output during the twenty hour tests. During 52 hours operation Tube SC4 power output dropped 22%. During 55 hours operation Tube RC13 power output did not change.

Since there were no failures on either manufacturer's tubes due to the Dynamic Tests, it cannot definitely be stated that Manufacturer "R" Tubes will outlast Manufacturer "S"



Tubes. It seems definitely proven: however, that the characteristics of Manufacturer "p" Tubes change less with operation under normal and overload conditions than do the characteristics of Manufacturer "s" Tubes. This change in characteristics results in the loss of power output observed in Manufacturer "s" Tubes.





#### CHAPTER IV

#### ATTEMPTED CORRELATION BETWEEN STATIC TESTS AND TUBE CHARACTERISTICS DURING LIFE

As was stated in the introduction, one of the purposes of the tests was to predict tube life under dynamic conditions from measurements made in a static tester. The following attempts at correlation were made. It is important to note that on the twenty hour tests of fifty Manufacturer "S" and forty Manufacturer "R" Tubes, there was but one failure. This failure occurred after 1/2 hour on a tube which prior to the actual test had been operated several hours at many different voltages in the simulator while the simulator was being set up. Because there was only one failure and this was on a tube whose  $G_m$  was only 1700 micromhos at the beginning of the test, as compared to 3700 micromhos average for the lot from which it was taken, the failure cannot be attributed

# CHAPTER IV

THEORY OF CORRELATION BETWEEN STATION TEMPERATURE AND WATER VAPOR PRESSURE

As was stated in the introduction, one of the purposes of the study was to predict the rate of change of dynamic conditions from measurements made in a single sector. The following attempts at correlation were made. It is important to note that in the twenty four cases of fifty measurements "E" and forty measurements "W" were, there was one and one-half. This failure occurred after 1/2 hour on a scale which prior to the second hour had been repeated several hours at many different values in the situation while the simulator was being set up. Because there was only one failure and this was on a time scale of only 1700 minutes at the beginning of the test, as compared to 2700 minutes average for the test from which it was taken, the failure seemed to be isolated

to the operation during the test period.

Since there were no failures of normal tubes, the best method of measuring useful life left in the tubes after test is to measure their transconductance. In the following attempts at correlation, this criterion was used.

The change in transconductance between normal plate voltage and normal plate voltage less 20 volts was computed from static tests. This change was compared with the final value of transconductance. The results showed no apparent correlation between change in  $g_m$  and final value of  $g_m$  as will be seen by referring to the tables below which are for tubes used in two separate tests.

Tube	Original $g_m$ micromho	Final $g_m$ Micromho	$\Delta g_m$ for $E_{plate}$ lowered 20 volts
8A-1	3600	3100	-725
2	3500	3000	-700
3	3920	3680	-1020
4	4320	3200	-825



to the question during the last period.  
 Since there were no failures of normal  
 tubes, the best method of measuring useful life  
 life in the tubes after test is to measure  
 their transconductance. In the following  
 attempts at correlation, this criterion was  
 used.  
 The change in transconductance between  
 normal plate voltage and normal plate voltage  
 was 50 volts was computed from each test.  
 This change was compared with the final value  
 of transconductance. The results showed no  
 apparent correlation between change in  $\mu$   
 and final value of  $\mu$  as will be seen by re-  
 turning to the table below which was for  
 tubes used in two separate series.

Tube Microhm	Final $\mu$ Microhm	$\Delta \mu$ for 50 volts
1-1	2500	-725
2	2500	-700
3	2500	-1000
4	2500	-825

Tube	Original $\mu_m$ micromho	Final $\mu_m$ Micromho	$\Delta \mu_m$ for $E_{plate}$ lowered 20 volts
SA-5	4200	3800	-870
6	3450	3300	-800
7	3500	3000	-800
EB-1	3630	3600	-650
2	4300	4270	-670
3	4000	3700	-530
4	3800	3730	-650
5	4550	4600	-650
6	3620	3300	-450
7	4150	3950	-550
8	3670	3520	-445
9	3900	3560	-520
10	4200	4400	-680

Similar comparisons made with ten other tubes of each type also failed to show any correlation between change in  $\mu_m$  and final value of  $\mu_m$ .

The next change investigated for possible relation to the final value of  $\mu_m$

Tube  
 Principal  
 Final  
 Δ for  
 please  
 lower  
 80

64-2	4200	4200	-870
64-3	4200	4200	-870
64-4	4200	4200	-870
64-5	4200	4200	-870
64-6	4200	4200	-870
64-7	4200	4200	-870
64-8	4200	4200	-870
64-9	4200	4200	-870
64-10	4200	4200	-870
64-11	4200	4200	-870
64-12	4200	4200	-870
64-13	4200	4200	-870
64-14	4200	4200	-870
64-15	4200	4200	-870
64-16	4200	4200	-870
64-17	4200	4200	-870
64-18	4200	4200	-870
64-19	4200	4200	-870
64-20	4200	4200	-870

Similar experiments were made with the  
 other tubes of each type also failed to show  
 any correlation between change in  $E_p$  and  $T_{\text{total}}$   
 value of  $E_p$ .

The next change investigated for  
 possible relation to the final value of  $E_p$

was the change in transconductance for a reduction in heater voltage from 6.3 to 4.0 volts. The percentage change in  $g_m$  at 4.0 volts was computed, and this was plotted against original  $g_m$  for several of the tubes of both manufacture that had been tested dynamically. It was thought possible that with such a plot one would be able to select quickly desirable tubes which had high  $g_m$  and small change in  $g_m$  for change in heater voltage. The data from which two such plots were made appears in Table I of Appendix II together with the predictions on the relative values of transconductance at the end of twenty hours operation. The tube which it was predicted would have highest value of  $g_m$  at the end of twenty hours operation was called 1st, the tube predicted to have next highest value 2nd and so forth. These predictions were made by using the plots of Plates IX and X. At the same time predictions were made on the



was the change in transconductance for a  
reduction in heater voltage from 6.2 to 4.0  
volts. The percentage change in  $R_p$  at 4.0  
volts was computed, and this was plotted  
against original  $R_p$  for several of the tubes  
of this manufacturer that had been tested  
hydraulically. It was thought possible that  
with such a plot one would be able to select  
quickly desirable tubes which had high  $R_p$   
and small change in  $R_p$  for change in heater  
voltage. The data from which two such plots  
were made appears in Table I of Appendix I.  
Consistent with the hypothesis on the relative  
values of transconductance at the end of  
twenty-hour operation, the tubes which it  
was predicted would have highest values of  $R_p$   
at the end of twenty-hour operation were called  
out, the tubes predicted to have next lowest  
values and so forth. These predictions were  
made by using the plots of Figure 7 and 8.  
At the time the predictions were made the

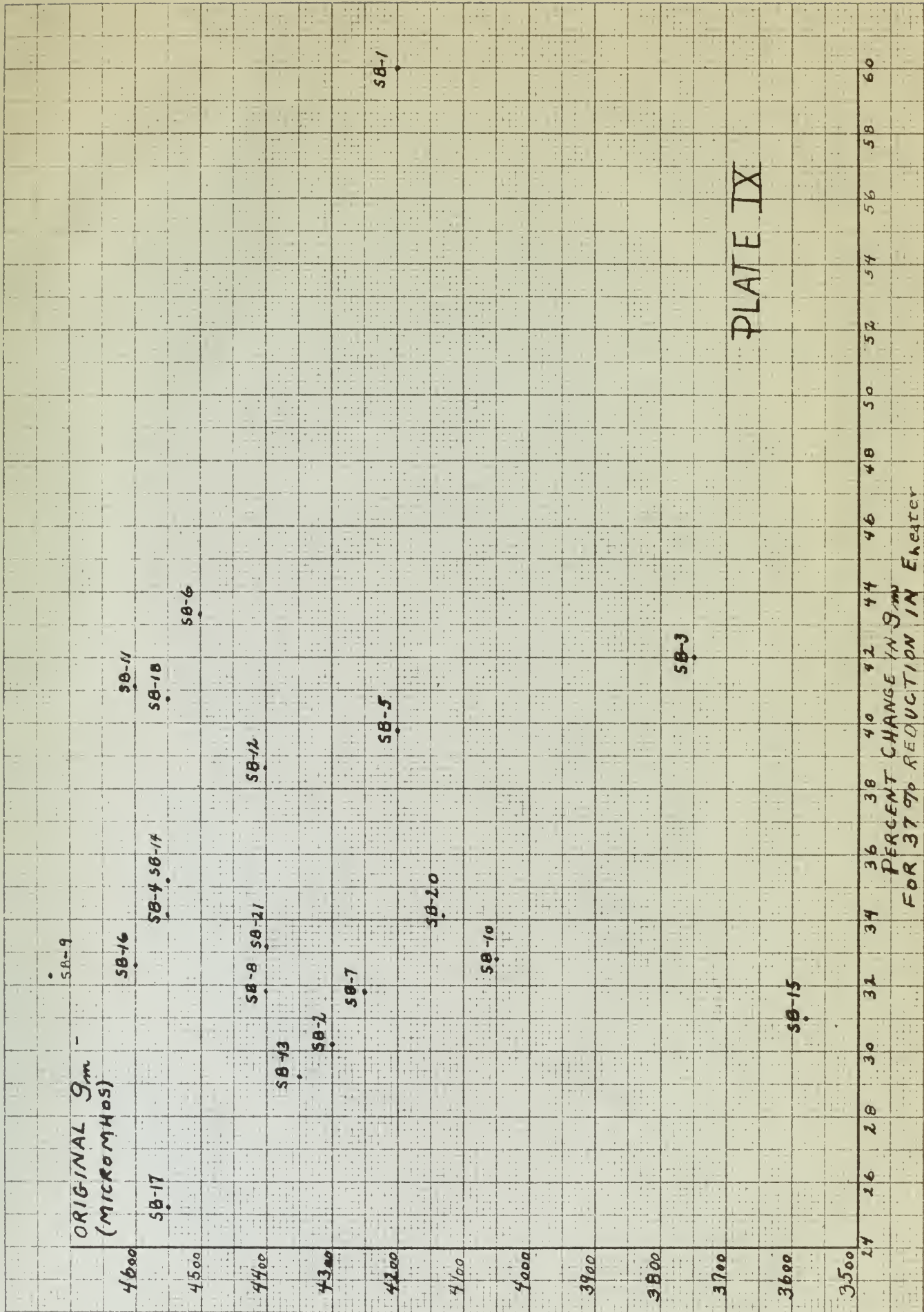


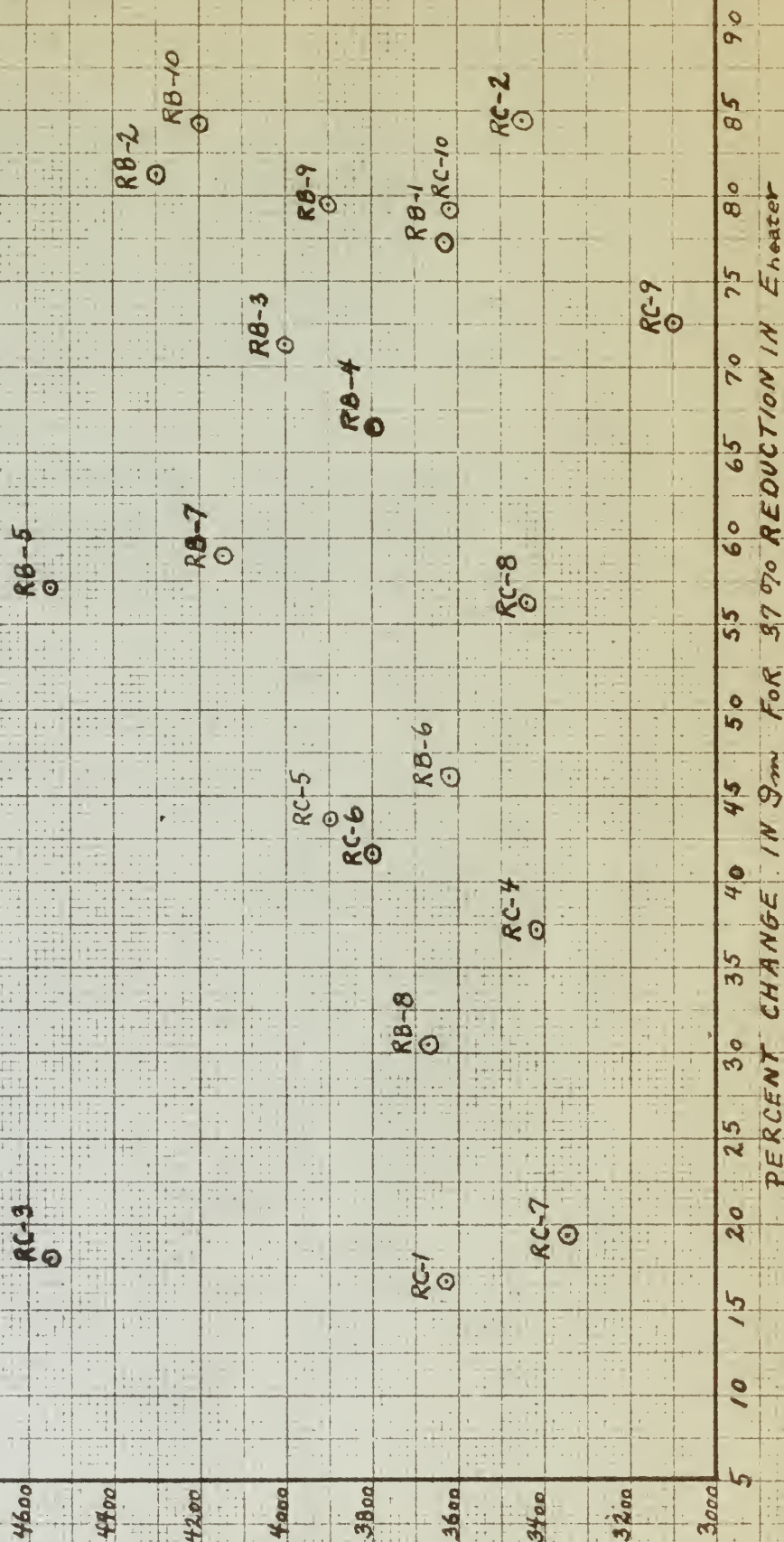
PLATE IX





ORIGINAL  
g<sub>m</sub>

# PLATE X







basis of original value of  $\epsilon_m$  alone. The errors in predicting the relative values of  $\epsilon_m$  after twenty hours operation by use of the plot and by use of the original value of  $\epsilon_m$  are given below for two groups of ten tubes each.

Tube	Error in relative $\epsilon_m$ after operation using original $\epsilon_m$ to predict	Error in relative $\epsilon_m$ after operation using plot to predict
SP-11	4	1
12	6	1
13	0	1
14	2	0
15	1	3
16	6	1
17	0	1
18	1	4
20	3	1
21	<u>3</u>	<u>1</u>
Average	2.0	Average 1.4
EB-1	2	1
2	1	2

scale of original value of  $R_{00}$  alone. The errors in predicting the relative values of  $R_{00}$  after twenty hours appear on the use of the first and by use of the original value of  $R_{00}$  are given below for two groups of ten subjects.

Type	Error in relative $R_{00}$ after operation using original $R_{00}$ as predictor	Error in relative $R_{00}$ after operation using first $R_{00}$ as predictor
17-18	2	1
18	3	1
19	0	1
14	3	0
15	1	2
16	0	1
17	0	1
18	1	2
20	3	1
21	3	1
Average	2.0	1.4
17-18	2	1
2	1	2

Tube	Error in relative $\epsilon_m$ after operation using original $\epsilon_m$ to predict	Error in relative $\epsilon_m$ after operation using plot to predict
SB-3	1	1
4	2	2
5	1	1
6	2	7
7	1	2
8	2	1
9	2	2
10	<u>2</u>	<u>1</u>
Average	1.7	Average 2.0

The results of four more tests of twenty hours each were used to make identical calculations. The computations will not be shown here but the results were:

Tube	Average error in relative $\epsilon_m$ after operation using original $\epsilon_m$ to predict	Average error in relative $\epsilon_m$ after operation using plot to predict
SA 2-13	2.60	3.40
SA 11-20	1.33	1.22
SB 1-10	1.00	2.60
SC 1-10	2.40	3.40



Run	Original $R_{\infty}$ to predicted	Error in relative $R_{\infty}$ after operation	Error in relative $R_{\infty}$ after operation $R_{\infty}$ after prediction
1	1	1	1
2	2	2	2
3	1	1	1
4	2	2	2
5	1	1	1
6	2	2	2
7	1	1	1
8	2	2	2
9	1	1	1
10	2	2	2
Average	1.7	Average	2.0

The results of four more tests of twenty hours each were used to make identical calculations. The calculations will not be shown here but the results were:

Run	Original $R_{\infty}$ to predicted	Average error in relative $R_{\infty}$ after operation using original $R_{\infty}$ to predicted	Average error in relative $R_{\infty}$ after operation using predicted
11-15	2.00	2.40	2.40
16-20	1.00	1.32	1.32
21-25	1.00	2.40	2.40
26-30	2.40	2.40	2.40

The results of the six tests show that the average error in relative  $g_m$  after test is usually less by using the original value of  $g_m$  to predict value after test. These results preclude the use of the plot as tubes that start life with high  $g_m$  usually continue to have high  $g_m$  relative to tubes starting life with low  $g_m$ .

The next quantity investigated for its effect on tube life was plate resistance. Values of  $r_p$  were computed at rated heater voltage and at 1.0 volts heater voltage. The change in plate voltage in each case was 20 volts.

Results of these computations are given in Table II of Appendix II for ten Manufacturer "G" and nine Manufacturer "K" Tubes. The  $\Delta r_p$  is simply change in  $r_p$  for a change of -2.3 volts heater voltage.

There appears to be no correlation between  $\Delta r_p$  and final value of  $g_m$  nor between  $\Delta r_p$  and  $\Delta g_m$ .

The results of the tests were that the average of the results of the tests is usually less than the average of the results of the tests of the same kind. This is due to the fact that the results of the tests of the same kind are usually less than the results of the tests of the same kind.

The results of the tests were that the average of the results of the tests is usually less than the average of the results of the tests of the same kind. This is due to the fact that the results of the tests of the same kind are usually less than the results of the tests of the same kind.

The results of the tests were that the average of the results of the tests is usually less than the average of the results of the tests of the same kind. This is due to the fact that the results of the tests of the same kind are usually less than the results of the tests of the same kind.

$\Delta$	$\Delta$	$\Delta$	$\Delta$
1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0

No further attempts were made to correlate the results of Static Tests with tube characteristics during life. A search of available literature failed to disclose any information as to what attempts had been made by others to perform such a correlation aside from making the usual measurements in a tester of Plate Current, Plate Resistance, and Transconductance at rated values of Plate and Heater Voltage.



No further attempts were made to  
correlate the results of these tests with  
some characteristics during life. A search  
of available literature failed to disclose  
any information as to what attempts had  
been made by others to perform such a  
correlation since from reading the usual  
monographs in a number of these countries,  
Italy, Germany, and Switzerland as  
well as those of Tiede and Hester Volz.

## Chapter V

### Conclusions

On the basis of static tests, Manufacturer "R" Tubes are more uniform in characteristics than Manufacturer "S" Tubes. "R" Tubes show fewer percentages of bad tubes from a random selection. Their parameters are more nearly what their manufacturers give as typical parameters.

The average value of transconductance, which is usually considered the best criterion of design proficiency of a tube, was greater for 98 Manufacturer "R" Tubes than for an equal number of Manufacturer "S" Tubes.

On the basis of dynamic tests simulating performance in one particular application, Manufacturer "R" Tubes show much smaller percentage change in both static characteristics and power output than Manufacturer "S" Tubes. While no definite value of tube life was obtained for either manufacturer's tubes, it



is highly probable that Manufacturer "P"  
Tubes will outlive Manufacturer "G" Tubes.

No simple method is apparent from the  
results of these experiments by which the  
parameters measured on static tests can be  
used to predict changes in characteristics  
which may result from tube operation.





# APPENDIX I

## TABLE I

<u>Manufacturer</u>	<u>Manufacturer's Lot No.</u>	<u>Symbol</u>	<u>Number of Tubes</u>	<u>Tube Designations</u>
"S"	R25589D	SA	35	SA1, SA2, ..., SA35
"S"	R25589C	SB	35	SB1, SB2, ..., SB35
"S"	R25295	SC	<u>35</u>	SC1, SC2, ..., SC35
		Total	105	
"R"	148	RA	10	RA1, RA2, ..., RA10
"R"	298	RB	26	RB1, RB2, ..., RA26
"R"	438	RC	24	RC1, RC2, ..., RC24
"R"	488	RD	<u>40</u>	RD1, RD2, ..., RD40
		Total	100	



TABLE II  
Manufacturer "S" - 6K4A Tubes

55890	Tube	Milliamp Iplate	Micromho gm	Ohms rp	Vari- ation from mean Ip	Vari- ation from mean rp	Vari- ation from mean gm
	SA 1	10.0	3600	4760	1.2	360	95
	" 2	10.3	3500	4700	.9	360	195
	" 3	11.7	3920	4760	.5	360	225
	" 4	12.8	4320	4445	1.6	45	625
	" 5	13.5	4200	3840	2.3	560	505
	" 6	9.5	3450	4650	1.7	250	245
	" 7	11.3	3500	3840	.1	560	195
	" 8	16.0	4400	3510	4.8	890	705
	" 9	10.0	3350	4050	1.2	250	345
	" 10	9.0	3120	4760	2.2	360	575
	" 11	14.0	4170	3510	2.8	890	475
	" 12	14.1	3900	3640	2.9	760	205
	" 13	8.8	3270	5125	2.4	725	425
	" 14	11.5	3650	4080	.3	320	45
	" 15	9.1	3370	5125	2.1	725	325
	" 16	9.0	3300	48.75	2.2	475	395
	" 17	11.6	3700	4000	.4	400	5
	" 18	10.3	3480	4545	.9	145	215



TABLE II

Penetration of  $\text{H}_2\text{O}$  - 60°C. 72 hrs.

Time in hr.	Weight loss g.	Weight loss g.	Weight loss g.	Weight loss g.	Weight loss g.
1	10.0	10.0	10.0	10.0	10.0
2	10.3	10.3	10.3	10.3	10.3
3	11.7	11.7	11.7	11.7	11.7
4	11.8	11.8	11.8	11.8	11.8
5	11.8	11.8	11.8	11.8	11.8
6	9.5	9.5	9.5	9.5	9.5
7	11.3	11.3	11.3	11.3	11.3
8	11.7	11.7	11.7	11.7	11.7
9	10.0	10.0	10.0	10.0	10.0
10	9.0	9.0	9.0	9.0	9.0
11	11.0	11.0	11.0	11.0	11.0
12	11.1	11.1	11.1	11.1	11.1
13	8.8	8.8	8.8	8.8	8.8
14	11.5	11.5	11.5	11.5	11.5
15	9.1	9.1	9.1	9.1	9.1
16	9.0	9.0	9.0	9.0	9.0
17	11.4	11.4	11.4	11.4	11.4
18	10.3	10.3	10.3	10.3	10.3

Tube	Milliamp Iplate	Micromho gm	Ohms rp	Vari- ation from mean Ip	Vari- ation from mean rp	Vari- ation from mean gm
SA19	8.7	3350	5125	2.5	715	31.5
" 20	11.9	3600	4000	.7	400	95
" 21	12.5	3820	3840	1.3	560	125
" 22	15.2	4400	3390	4.3	1010	705
" 23	15.8	4620	3570	4.6	830	925
" 24	9.0	3320	5000	2.2	600	375
" 25	10.4	3600	4445	.8	45	95
" 26	9.1	3300	5260	2.1	860	395
" 27	12.3	3870	3920	1.1	480	175
" 28	Bad Tube					
" 29	8.5	3400	5550	2.7	1150	295
" 30	11.7	3920	4445	.5	45	225
" 31	11.7	3950	4080	.5	320	255
" 32	10.5	3700	4445	.7	45	5
" 33	13.0	3720	3840	1.8	560	25
" 34	8.7	3240	5125	2.5	725	455
" 35	9.8	3500	4550	1.4	250	195
Totals	381.3	125510	149610	60.2	16000	10610
Average = 1/34 x Totals	11.20	3695	4400	1.77	470	312

Year	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099
1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	

TABLE III

Manufacturer "S" - OKA Tubes

t R255890	Tube	Milliamp	Microhm	Ohms	Vari-	Vari-	Vari-
		Inplate	<u>Ω</u>	<u>rp</u>	ation from mean Ip	ation from mean rp	ation from mean gm
	SB 1	11.4	4200	4000	1.2	530	120
	" 2	11.4	4300	3700	1.2	230	20
	" 3	12.1	3750	4080	3.5	610	570
	" 4	16.9	4550	3330	1.3	110	230
	" 5	15.5	4200	3640	0.1	170	120
	" 6	17.1	4500	3080	1.5	390	180
	" 7	15.8	4250	3180	.2	290	70
	" 8	15.0	4400	3445	.6	25	80
	" 9	17.3	4730	3180	1.7	390	410
	" 10	11.0	4050	3450	1.6	20	270
	" 11	19.0	4600	2990	3.4	450	260
	" 12	17.3	4400	3445	1.7	25	80
	" 13	11.4	4350	3510	1.2	40	30
	" 14	16.8	4550	3330	1.2	110	230
	" 15	11.9	3580	3920	3.7	450	740
	" 16	15.8	4000	3510	.2	40	280
	" 17	15.6	4550	3700	.0	230	230
	" 18	18.4	4550	2940	3.2	530	230



Station	Time	Lat.	Long.	Alt.	Temp.	Wind	Clouds	Remarks
1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1
2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2
3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4
5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7
8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8
9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
10	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
11	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1
12	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
13	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3
14	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4
15	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
16	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
17	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
18	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8
19	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9
20	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0

<u>Tube</u>	<u>Milliamp I<sub>plate</sub></u>	<u>Microsho gm</u>	<u>Ohms rp</u>	<u>Vari- ation from mean I<sub>p</sub></u>	<u>Vari- ation from mean rp</u>	<u>Vari- ation from mean gm</u>
3B 19	Bad Tube					
" 20	16.5	4130	3510	.9	40	190
" 21	15.5	4400	3700	.1	230	80
" 22	19.0	4585	3175	3.4	295	200
" 23	12.3	3900	3775	3.3	305	420
" 24	13.1	4200	3575	2.5	105	120
" 25	18.2	4400	3125	2.6	345	80
" 26	17.3	4600	3175	1.7	295	280
" 27	16.0	4420	3640	.4	170	100
" 28	15.3	4070	3390	.3	80	250
" 29	15.3	4320	3570	.3	100	0
" 30	15.3	4200	3390	.3	80	120
" 31	15.0	4400	3700	.0	230	80
" 32	16.3	4600	3450	.7	20	280
" 33	Bad Tube					
" 34	13.1	3820	3510	2.5	40	500
" 35	14.5	4480	3390	1.1	80	160
Totals	524.0	142630	114505	47.6	7245	7090
Average = 1/33 x Total						
	15.6	4320	3470	1.44	216.2	214.7

Year	Value	Year	Value	Year	Value	Year	Value
1970	100	1971	105	1972	110	1973	115
1974	120	1975	125	1976	130	1977	135
1978	140	1979	145	1980	150	1981	155
1982	160	1983	165	1984	170	1985	175
1986	180	1987	185	1988	190	1989	195
1990	200	1991	205	1992	210	1993	215
1994	220	1995	225	1996	230	1997	235
1998	240	1999	245	2000	250	2001	255
2002	260	2003	265	2004	270	2005	275
2006	280	2007	285	2008	290	2009	295
2010	300	2011	305	2012	310	2013	315
2014	320	2015	325	2016	330	2017	335
2018	340	2019	345	2020	350	2021	355
2022	360	2023	365	2024	370	2025	375

TABLE IV

Manufacturer "S" - 6KHA Tubes

R26255	Tube	Milliamp Iplate	Microhm gm	Ohms rp	Vari- ation from mean Ip	Vari- ation from mean rp	Vari- ation from mean gm
	SC 1	11.3	3400	3920	0	130	275
	" 2	12.0	3920	3920	.7	130	245
	" 3	10.3	3520	4445	1.0	295	155
	" 4	13.8	4100	3570	2.5	580	485
	" 5	8.2	3300	5950	3.1	1400	375
	" 6	14.0	4350	3510	2.7	640	675
	" 7	10.6	3820	4445	.7	295	145
	" 8	Bad Tube					
	" 9	10.6	3600	4350	.7	200	75
	" 10	11.3	3750	4170	.0	80	75
	" 11	13.4	4120	3920	2.1	230	445
	" 12	Bad Tube					
	" 13	12.8	4450	3775	1.5	375	775
	" 14	14.3	4250	3125	3.0	1025	575
	" 15	Bad Tube					
	" 16	10.0	3000	4250	1.3	100	15
	" 17	13.4	4470	3635	2.1	515	795
	" 18	10.3	3350	4170	1.0	20	325



TABLE IV						
Average monthly precipitation, 1901-1910						
Station	Jan.	Feb.	Mar.	Apr.	May	June
1	1.2	1.5	1.8	2.1	2.4	2.7
2	1.3	1.6	1.9	2.2	2.5	2.8
3	1.4	1.7	2.0	2.3	2.6	2.9
4	1.5	1.8	2.1	2.4	2.7	3.0
5	1.6	1.9	2.2	2.5	2.8	3.1
6	1.7	2.0	2.3	2.6	2.9	3.2
7	1.8	2.1	2.4	2.7	3.0	3.3
8	1.9	2.2	2.5	2.8	3.1	3.4
9	2.0	2.3	2.6	2.9	3.2	3.5
10	2.1	2.4	2.7	3.0	3.3	3.6
11	2.2	2.5	2.8	3.1	3.4	3.7
12	2.3	2.6	2.9	3.2	3.5	3.8
13	2.4	2.7	3.0	3.3	3.6	3.9
14	2.5	2.8	3.1	3.4	3.7	4.0
15	2.6	2.9	3.2	3.5	3.8	4.1
16	2.7	3.0	3.3	3.6	3.9	4.2
17	2.8	3.1	3.4	3.7	4.0	4.3
18	2.9	3.2	3.5	3.8	4.1	4.4
19	3.0	3.3	3.6	3.9	4.2	4.5
20	3.1	3.4	3.7	4.0	4.3	4.6
21	3.2	3.5	3.8	4.1	4.4	4.7
22	3.3	3.6	3.9	4.2	4.5	4.8
23	3.4	3.7	4.0	4.3	4.6	4.9
24	3.5	3.8	4.1	4.4	4.7	5.0
25	3.6	3.9	4.2	4.5	4.8	5.1
26	3.7	4.0	4.3	4.6	4.9	5.2
27	3.8	4.1	4.4	4.7	5.0	5.3
28	3.9	4.2	4.5	4.8	5.1	5.4
29	4.0	4.3	4.6	4.9	5.2	5.5
30	4.1	4.4	4.7	5.0	5.3	5.6
31	4.2	4.5	4.8	5.1	5.4	5.7
32	4.3	4.6	4.9	5.2	5.5	5.8
33	4.4	4.7	5.0	5.3	5.6	5.9
34	4.5	4.8	5.1	5.4	5.7	6.0
35	4.6	4.9	5.2	5.5	5.8	6.1
36	4.7	5.0	5.3	5.6	5.9	6.2
37	4.8	5.1	5.4	5.7	6.0	6.3
38	4.9	5.2	5.5	5.8	6.1	6.4
39	5.0	5.3	5.6	5.9	6.2	6.5
40	5.1	5.4	5.7	6.0	6.3	6.6
41	5.2	5.5	5.8	6.1	6.4	6.7
42	5.3	5.6	5.9	6.2	6.5	6.8
43	5.4	5.7	6.0	6.3	6.6	6.9
44	5.5	5.8	6.1	6.4	6.7	7.0
45	5.6	5.9	6.2	6.5	6.8	7.1
46	5.7	6.0	6.3	6.6	6.9	7.2
47	5.8	6.1	6.4	6.7	7.0	7.3
48	5.9	6.2	6.5	6.8	7.1	7.4
49	6.0	6.3	6.6	6.9	7.2	7.5
50	6.1	6.4	6.7	7.0	7.3	7.6
51	6.2	6.5	6.8	7.1	7.4	7.7
52	6.3	6.6	6.9	7.2	7.5	7.8
53	6.4	6.7	7.0	7.3	7.6	7.9
54	6.5	6.8	7.1	7.4	7.7	8.0
55	6.6	6.9	7.2	7.5	7.8	8.1
56	6.7	7.0	7.3	7.6	7.9	8.2
57	6.8	7.1	7.4	7.7	8.0	8.3
58	6.9	7.2	7.5	7.8	8.1	8.4
59	7.0	7.3	7.6	7.9	8.2	8.5
60	7.1	7.4	7.7	8.0	8.3	8.6
61	7.2	7.5	7.8	8.1	8.4	8.7
62	7.3	7.6	7.9	8.2	8.5	8.8
63	7.4	7.7	8.0	8.3	8.6	8.9
64	7.5	7.8	8.1	8.4	8.7	9.0
65	7.6	7.9	8.2	8.5	8.8	9.1
66	7.7	8.0	8.3	8.6	8.9	9.2
67	7.8	8.1	8.4	8.7	9.0	9.3
68	7.9	8.2	8.5	8.8	9.1	9.4
69	8.0	8.3	8.6	8.9	9.2	9.5
70	8.1	8.4	8.7	9.0	9.3	9.6
71	8.2	8.5	8.8	9.1	9.4	9.7
72	8.3	8.6	8.9	9.2	9.5	9.8
73	8.4	8.7	9.0	9.3	9.6	9.9
74	8.5	8.8	9.1	9.4	9.7	10.0
75	8.6	8.9	9.2	9.5	9.8	10.1
76	8.7	9.0	9.3	9.6	9.9	10.2
77	8.8	9.1	9.4	9.7	10.0	10.3
78	8.9	9.2	9.5	9.8	10.1	10.4
79	9.0	9.3	9.6	9.9	10.2	10.5
80	9.1	9.4	9.7	10.0	10.3	10.6
81	9.2	9.5	9.8	10.1	10.4	10.7
82	9.3	9.6	9.9	10.2	10.5	10.8
83	9.4	9.7	10.0	10.3	10.6	10.9
84	9.5	9.8	10.1	10.4	10.7	11.0
85	9.6	9.9	10.2	10.5	10.8	11.1
86	9.7	10.0	10.3	10.6	10.9	11.2
87	9.8	10.1	10.4	10.7	11.0	11.3
88	9.9	10.2	10.5	10.8	11.1	11.4
89	10.0	10.3	10.6	10.9	11.2	11.5
90	10.1	10.4	10.7	11.0	11.3	11.6
91	10.2	10.5	10.8	11.1	11.4	11.7
92	10.3	10.6	10.9	11.2	11.5	11.8
93	10.4	10.7	11.0	11.3	11.6	11.9
94	10.5	10.8	11.1	11.4	11.7	12.0
95	10.6	10.9	11.2	11.5	11.8	12.1
96	10.7	11.0	11.3	11.6	11.9	12.2
97	10.8	11.1	11.4	11.7	12.0	12.3
98	10.9	11.2	11.5	11.8	12.1	12.4
99	11.0	11.3	11.6	11.9	12.2	12.5
100	11.1	11.4	11.7	12.0	12.3	12.6

<u>Tube</u>	<u>Milliamp Iplate</u>	<u>Micromho gm</u>	<u>Ohms rp</u>	<u>Vari- ation from mean Ip</u>	<u>Vari- ation from mean rp</u>	<u>Vari- ation from mean gm</u>
SG19	14.5	3900	3570	3.2	580	225
" 20	10.6	3500	4000	.7	150	175
" 21	13.5	4190	3775	2.2	375	515
" 22	8.9	3330	5260	2.4	1110	345
" 23	10.6	3620	4080	.7	70	55
" 24	9.1	3300	4760	2.2	610	375
" 25	10.3	3500	4350	1.0	200	175
" 26	12.0	3800	3845	.7	305	125
" 27	10.1	3680	4255	1.2	105	5
" 28	11.3	3680	4170	0	20	5
" 29	Bad Tube					
" 30	9.5	3400	4760	1.8	610	275
" 31	13.5	3910	3700	2.2	450	235
" 32	8.8	3400	4060	2.5	70	275
" 33	12.3	3800	3700	1.0	450	125
" 34	12.0	3920	4250	.7	150	245
" 35	7.9	3200	5550	3.4	1400	475
Totals	351.2	116250	128860	48.3	12670	9065
Average = 1/31 x Totals						
	11.3	3675	4150	1.56	408	292

Time	Latitude	Longitude	Flow ft	Water level ft	Water level ft	Water level ft
0112	21.2	1300	3070	3.1	280	21.2
" 20	20.0	3000	1000	7	120	17.0
" 21	21.7	1100	3172	4.1	372	17.2
" 22	21.2	3000	4000	0.1	210	20.2
" 23	20.0	3000	1000	7	70	22
" 24	21	1300	1700	1.1	410	21.2
" 25	20.2	3000	1000	1.0	200	17.2
" 26	21.0	3000	3022	7	302	17.2
" 27	20.1	3000	1122	1.2	102	2
" 28	21.2	3000	1170	0	20	2
" 29	(See Table)					
" 30	21.2	3000	1700	1.0	400	17.2
" 31	21.2	3000	3700	2.2	120	17.2
" 32	20.2	3000	1000	0.2	70	17.2
" 33	20.2	3000	1700	1.0	120	17.2
" 34	21.0	3000	1000	7	120	20.2
" 35	21.2	3000	1700	1.1	120	17.2
Total = 21.2	13000	10000	10.2	12020	2002	2002
Average = 21.2 + 20.2						
21.2	2077	1120	1.20	100	100	100

TABLE V  
Manufacturer "R" - CK608CX Tubes

Lot 148				Vari-	Vari-	Vari-
<u>Tube</u>	<u>Milliamps</u> <u>Ip/plate</u>	<u>Micronho</u> <u>gn</u>	<u>Ohms</u> <u>rp</u>	<u>ation</u> <u>from</u> <u>mean Ip</u>	<u>ation</u> <u>from</u> <u>mean rp</u>	<u>ation</u> <u>from</u> <u>mean gn</u>
RA 1	10.3	4150	5260	1.4	940	0
" 2	11.0	3840	4650	.7	330	310
" 3	13.0	4220	3775	1.3	545	70
" 4	11.5	4400	4080	.2	240	250
" 5	13.4	4650	3920	1.7	400	500
" 6	10.3	3630	4160	1.4	160	520
" 7	Bad Tube					
" 8	12.2	4080	4250	.5	70	70
" 9	12.6	4320	4350	.9	30	170
" 10	11.0	4000	4445	.7	125	150
Totals	105.3	37290	38900	8.8	2840	2040
Average = $1/9 \times$ Totals						
	11.7	4150	4320	.98	316	226.5



[illegible]

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TABLE VI

Manufacturer "P" - 6XAO8CX Tubes

Lot 296						
Tube	Milliamps Inplate	Micromho gm	Class rp	Vari- ation from mean Ip	Vari- ation from mean rp	Vari- ation from mean gm
8B 1	7.7	3630	6250	3.3	1370	350
" 2	12.4	4300	4075	1.4	805	320
" 3	11.5	4000	4700	.5	120	20
" 4	10.4	3800	5000	.6	120	180
" 5	13.3	4550	4000	2.3	800	570
" 6	10.2	3620	5000	.8	120	360
" 7	10.7	4150	4675	.3	5	170
" 8	9.1	3670	6450	1.9	1570	310
" 9	10.2	3900	4875	.8	5	60
" 10	11.1	4200	4250	.1	630	220
" 11	10.4	4000	5100	.6	520	20
" 12	13.2	4150	4000	2.2	880	470
" 13	10.7	3900	4650	.3	230	80
" 14	11.0	3810	4875	.0	5	110

# TABLE II

Standardized  $\chi^2$  -  $\chi^2$  distribution

Y-axis value from table	Y-axis value from table	Y-axis value from table	Y-axis value from table	Y-axis value from table	Y-axis value from table	Y-axis value from table
0.01	0.01	0.01	0.01	0.01	0.01	0.01
0.02	0.02	0.02	0.02	0.02	0.02	0.02
0.03	0.03	0.03	0.03	0.03	0.03	0.03
0.04	0.04	0.04	0.04	0.04	0.04	0.04
0.05	0.05	0.05	0.05	0.05	0.05	0.05
0.06	0.06	0.06	0.06	0.06	0.06	0.06
0.07	0.07	0.07	0.07	0.07	0.07	0.07
0.08	0.08	0.08	0.08	0.08	0.08	0.08
0.09	0.09	0.09	0.09	0.09	0.09	0.09
0.10	0.10	0.10	0.10	0.10	0.10	0.10
0.11	0.11	0.11	0.11	0.11	0.11	0.11
0.12	0.12	0.12	0.12	0.12	0.12	0.12
0.13	0.13	0.13	0.13	0.13	0.13	0.13
0.14	0.14	0.14	0.14	0.14	0.14	0.14
0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.16	0.16	0.16	0.16	0.16	0.16	0.16
0.17	0.17	0.17	0.17	0.17	0.17	0.17
0.18	0.18	0.18	0.18	0.18	0.18	0.18
0.19	0.19	0.19	0.19	0.19	0.19	0.19
0.20	0.20	0.20	0.20	0.20	0.20	0.20

<u>Tube</u>	<u>Milliamps Iplate</u>	<u>Micromho gm</u>	<u>Ohms rp</u>	<u>Vari- ation from mean Ip</u>	<u>Vari- ation from mean rp</u>	<u>Vari- ation from mean gm</u>
RB15	12.3	4220	4445	1.3	435	240
" 16	13.1	4380	4550	2.1	330	400
" 17	10.8	3760	4760	.2	120	200
" 18	13.2	4200	4060	2.2	800	220
" 19	12.2	4020	4590	1.2	330	40
" 20	11.2	3820	4875	.2	5	160
" 21	10.2	3800	5200	.8	380	180
" 22	11.4	3800	4875	.4	5	180
" 23	9.2	3900	5700	1.8	820	80
" 24	9.8	3770	5125	1.2	245	210
" 25	10.7	4100	4650	.3	230	120
" 26	9.4	3700	5550	1.6	670	280
Totals	285.4	103500	126900	28.5	11550	5600
Average = 1/26 x Totals						
	11.0	3980	4880	1.095	444	215





TABLE VII

Manufacturer "A" - 3X00007 Tubes

Lot L38						
<u>Tube</u>	<u>Milliamps Iplate</u>	<u>Micromho gm</u>	<u>Ohms rp</u>	<u>Vari- ation from mean Ip</u>	<u>Vari- ation from mean rp</u>	<u>Vari- ation from mean gm</u>
RG 1	10.3	3630	5260	1.3	670	30
" 2	8.9	3450	5715	.1	215	210
" 3	5.5	4590	7400	3.5	1470	890
" 4	8.4	3420	6900	.6	970	240
" 5	8.4	3900	5880	.6	50	240
" 6	11.5	3800	5000	2.5	930	140
" 7	10.4	3350	5100	1.4	530	310
" 8	10.2	3440	5125	1.2	805	110
" 9	7.0	3100	6450	2.0	520	500
" 10	8.2	3620	8340	.8	2410	40
" 11	7.6	3600	6060	1.4	130	60
" 12	8.7	3550	5720	.3	210	120

Year	Month	Day	Time	Location	Remarks
1944	Jan	1	10:00	1000	1000
1944	Jan	2	10:00	1000	1000
1944	Jan	3	10:00	1000	1000
1944	Jan	4	10:00	1000	1000
1944	Jan	5	10:00	1000	1000
1944	Jan	6	10:00	1000	1000
1944	Jan	7	10:00	1000	1000
1944	Jan	8	10:00	1000	1000
1944	Jan	9	10:00	1000	1000
1944	Jan	10	10:00	1000	1000
1944	Jan	11	10:00	1000	1000
1944	Jan	12	10:00	1000	1000
1944	Jan	13	10:00	1000	1000
1944	Jan	14	10:00	1000	1000
1944	Jan	15	10:00	1000	1000
1944	Jan	16	10:00	1000	1000
1944	Jan	17	10:00	1000	1000
1944	Jan	18	10:00	1000	1000
1944	Jan	19	10:00	1000	1000
1944	Jan	20	10:00	1000	1000
1944	Jan	21	10:00	1000	1000
1944	Jan	22	10:00	1000	1000
1944	Jan	23	10:00	1000	1000
1944	Jan	24	10:00	1000	1000
1944	Jan	25	10:00	1000	1000
1944	Jan	26	10:00	1000	1000
1944	Jan	27	10:00	1000	1000
1944	Jan	28	10:00	1000	1000
1944	Jan	29	10:00	1000	1000
1944	Jan	30	10:00	1000	1000
1944	Jan	31	10:00	1000	1000

Year	Month	Day	Time	Location	Remarks
1944	Jan	1	10:00	1000	1000
1944	Jan	2	10:00	1000	1000
1944	Jan	3	10:00	1000	1000
1944	Jan	4	10:00	1000	1000
1944	Jan	5	10:00	1000	1000
1944	Jan	6	10:00	1000	1000
1944	Jan	7	10:00	1000	1000
1944	Jan	8	10:00	1000	1000
1944	Jan	9	10:00	1000	1000
1944	Jan	10	10:00	1000	1000
1944	Jan	11	10:00	1000	1000
1944	Jan	12	10:00	1000	1000
1944	Jan	13	10:00	1000	1000
1944	Jan	14	10:00	1000	1000
1944	Jan	15	10:00	1000	1000
1944	Jan	16	10:00	1000	1000
1944	Jan	17	10:00	1000	1000
1944	Jan	18	10:00	1000	1000
1944	Jan	19	10:00	1000	1000
1944	Jan	20	10:00	1000	1000
1944	Jan	21	10:00	1000	1000
1944	Jan	22	10:00	1000	1000
1944	Jan	23	10:00	1000	1000
1944	Jan	24	10:00	1000	1000
1944	Jan	25	10:00	1000	1000
1944	Jan	26	10:00	1000	1000
1944	Jan	27	10:00	1000	1000
1944	Jan	28	10:00	1000	1000
1944	Jan	29	10:00	1000	1000
1944	Jan	30	10:00	1000	1000
1944	Jan	31	10:00	1000	1000

<u>Tube</u>	<u>Milliamps</u> <u>Iplate</u>	<u>Microhmho</u> <u>gm</u>	<u>Ohms</u> <u>rp</u>	<u>Vari-</u> <u>ation</u> <u>from</u> <u>mean lp</u>	<u>Vari-</u> <u>ation</u> <u>from</u> <u>mean rp</u>	<u>Vari-</u> <u>ation</u> <u>from</u> <u>mean gm</u>
RC13	8.6	3700	6450	.4	520	40
" 14	5.8	3080	8340	3.2	2410	580
" 15	10.2	3500	5400	1.2	530	160
" 16	10.2	3500	5400	1.2	530	160
" 17	7.6	3330	7150	1.4	1220	330
" 18	8.9	3480	5750	.1	380	180
" 19	10.9	4000	4700	1.9	1170	340
" 20	8.2	3000	6450	.8	520	60
" 21	Bad Tube					
" 22	10.4	4200	5130	1.4	800	510
" 23	10.2	4100	4760	1.2	1170	440
" 24	11.0	4260	3570	2.0	2360	600
Totals	207.3	84160	136210	30.5	20520	6460
Average = 1/23 x Totals						
	9.0	3660	5930	1.325	892	281



Tube	Wavelength microns	Attenuation cm <sup>-1</sup>	Attenuation cm <sup>-1</sup>	Wavelength microns	Attenuation cm <sup>-1</sup>
201	8.0	1700	6000	4.0	200
* 19	7.0	3000	6500	3.5	200
* 18	6.0	2700	6200	3.0	200
* 16	5.0	1000	6000	2.5	200
* 17	4.0	3300	7100	2.0	200
* 15	3.5	1500	6000	1.5	200
* 14	3.0	1400	6700	1.0	200
* 20	2.5	3000	6000	.8	200
* 21	Total Time				
* 22	2.5	1000	6700	2.0	200
* 23	2.0	1200	6700	1.5	200
* 24	1.5	1000	6700	1.0	200
<hr/>					
Total	207.5	6000	13610	34.2	2000
Average = 1/20 * Total					
11	2.0	2000	2800	2.25	200
12	1.5	1000	1000	1.0	200

TABLE VIII

Manufacturer "R" - 6X600CK Tubes

Lot 488						
Tube	Milliamps Ip/plate	Micronho	Class rp	Vari- ation from mean Ip	Vari- ation from mean rp	Vari- ation from mean <u>ra</u>
RD 1	9.1	3800	5400	.7	220	245
" 2	7.8	3640	6050	2.0	870	405
" 3	8.8	3800	5710	1.0	530	245
" 4	10.1	3900	4540	.3	640	145
" 5	9.8	3940	4880	0	300	105
" 6	9.0	3700	5710	.8	530	345
" 7	11.7	4420	4440	1.9	740	375
" 8	10.6	4180	4700	.8	420	135
" 9	10.4	4300	4650	.6	530	155
" 10	10.5	4120	4760	.7	420	75
" 11	10.4	4100	4880	.6	300	55
" 12	9.2	4000	5400	.4	220	45
" 13	8.6	4000	5880	1.2	700	45

Year	Month	Day	Time	Location	Event	Notes
1992	Jan	1	10:00	1000	1000	1000
1992	Jan	2	10:00	1000	1000	1000
1992	Jan	3	10:00	1000	1000	1000
1992	Jan	4	10:00	1000	1000	1000
1992	Jan	5	10:00	1000	1000	1000
1992	Jan	6	10:00	1000	1000	1000
1992	Jan	7	10:00	1000	1000	1000
1992	Jan	8	10:00	1000	1000	1000
1992	Jan	9	10:00	1000	1000	1000
1992	Jan	10	10:00	1000	1000	1000
1992	Jan	11	10:00	1000	1000	1000
1992	Jan	12	10:00	1000	1000	1000
1992	Jan	13	10:00	1000	1000	1000
1992	Jan	14	10:00	1000	1000	1000
1992	Jan	15	10:00	1000	1000	1000
1992	Jan	16	10:00	1000	1000	1000
1992	Jan	17	10:00	1000	1000	1000
1992	Jan	18	10:00	1000	1000	1000
1992	Jan	19	10:00	1000	1000	1000
1992	Jan	20	10:00	1000	1000	1000
1992	Jan	21	10:00	1000	1000	1000
1992	Jan	22	10:00	1000	1000	1000
1992	Jan	23	10:00	1000	1000	1000
1992	Jan	24	10:00	1000	1000	1000
1992	Jan	25	10:00	1000	1000	1000
1992	Jan	26	10:00	1000	1000	1000
1992	Jan	27	10:00	1000	1000	1000
1992	Jan	28	10:00	1000	1000	1000
1992	Jan	29	10:00	1000	1000	1000
1992	Jan	30	10:00	1000	1000	1000
1992	Jan	31	10:00	1000	1000	1000

<u>Tube</u>	<u>Milliamps Ip/ate</u>	<u>Micromho gm</u>	<u>Ohms rp</u>	<u>Vari- ation from mean Ip</u>	<u>Vari- ation from mean rp</u>	<u>Vari- ation from mean gm</u>
RD 14	8.8	3870	5550	1.0	370	175
" 15	11.2	4000	4880	1.4	300	45
" 16	10.7	4500	4760	.9	420	455
" 17	13.4	4400	4080	3.6	1180	355
" 18	10.4	4000	5330	.6	150	45
" 19	10.0	4080	4550	.2	630	35
" 20	8.4	3700	6055	1.4	875	345
" 21	10.4	4130	4760	.6	420	135
" 22	11.4	4670	4265	1.6	1015	625
" 23	8.8	3720	5880	1.0	700	325
" 24	7.8	3800	6250	2.0	1070	245
" 25	10.2	4100	4880	.4	300	55
" 26	8.2	3850	5550	1.6	370	195



Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100
1990	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100

Tube	Milliamps Inplate	Micromho <del>gm</del>	Ohms rp	Vari- ation from mean Ip	Vari- ation from mean rp	Vari- ation from mean gm
RD27	11.4	4470	4760	1.6	420	425
" 28	8.5	4050	6050	1.3	870	5
" 29	10.5	4360	4250	.7	930	335
" 30	10.2	4050	5130	.4	50	5
" 31	10.2	4100	5000	.4	180	55
" 32	9.2	4320	4880	.6	300	175
" 33	9.9	4100	4760	.1	420	55
" 34	8.2	3050	6040	1.6	860	395
" 35	10.2	4230	4880	.4	300	185
" 36	11.0	4150	4445	1.2	735	105
" 37	8.8	3700	5710	1.0	530	345
" 38	10.2	4040	4880	.4	300	5
" 39	9.5	4100	5260	.3	80	55
" 40	8.4	3800	5630	1.4	450	245
Totals	391.9	161810	205405	28.7	1002.5	7800
Average = 1/40 x Totals						
	9.8	4045	5180	.717	266	195



TABLE IX  
Average Variation from Mean Value

<u>Tube Group</u>	<u>I<sub>plate</sub></u>	<u>Weighting Factor</u>	<u>Weighted Mean I<sub>p</sub></u>
Manufacturer "S"			
SA	1.77	34/98	$1.77 \times 34 = 60.20$
SB	1.44	33/98	$1.44 \times 33 = 47.50$
SC	1.56	31/98	$1.56 \times 31 = 48.30$
			sum 156.00
			$156.0 \div 98 = 1.591$
Manufacturer "R"			
RA	.98	9/98	$.98 \times 9 = 8.82$
RB	1.01	26/98	$1.01 \times 26 = 26.25$
RC	1.33	23/98	$1.33 \times 23 = 30.60$
RD	.72	40/98	$.72 \times 40 = 28.80$
			sum 94.47
			$94.47 \div 98 = .963$



# TABLE II

Approximate Values of Functions

Approximate Values of Functions	Approximate Values of Functions	Approximate Values of Functions	Approximate Values of Functions
$1.77 \times 10 = 17.7$	$1.77 \times 10 = 17.7$	$1.77 \times 10 = 17.7$	$1.77 \times 10 = 17.7$
$1.77 \times 20 = 35.4$	$1.77 \times 20 = 35.4$	$1.77 \times 20 = 35.4$	$1.77 \times 20 = 35.4$
$1.77 \times 30 = 53.1$	$1.77 \times 30 = 53.1$	$1.77 \times 30 = 53.1$	$1.77 \times 30 = 53.1$
$1.77 \times 40 = 70.8$	$1.77 \times 40 = 70.8$	$1.77 \times 40 = 70.8$	$1.77 \times 40 = 70.8$
$1.77 \times 50 = 88.5$	$1.77 \times 50 = 88.5$	$1.77 \times 50 = 88.5$	$1.77 \times 50 = 88.5$
$1.77 \times 60 = 106.2$	$1.77 \times 60 = 106.2$	$1.77 \times 60 = 106.2$	$1.77 \times 60 = 106.2$
$1.77 \times 70 = 123.9$	$1.77 \times 70 = 123.9$	$1.77 \times 70 = 123.9$	$1.77 \times 70 = 123.9$
$1.77 \times 80 = 141.6$	$1.77 \times 80 = 141.6$	$1.77 \times 80 = 141.6$	$1.77 \times 80 = 141.6$
$1.77 \times 90 = 159.3$	$1.77 \times 90 = 159.3$	$1.77 \times 90 = 159.3$	$1.77 \times 90 = 159.3$
$1.77 \times 100 = 177.0$	$1.77 \times 100 = 177.0$	$1.77 \times 100 = 177.0$	$1.77 \times 100 = 177.0$

TABLE X

<u>Tube Lot</u>	<u>Tube</u>	<u><math>I_p</math> at <math>E_p</math> of 100 V.</u>	<u><math>I_p</math> at <math>E_p</math> of 80 V.</u>	<u><math>I_p</math> at <math>E_p</math> of 60 V.</u>	<u><math>I_p</math> at <math>E_p</math> of 50 V.</u>	<u><math>I_p</math> at <math>E_p</math> of 33 V.</u>
SA	Manufacturers	12.2	7.6	4.0	2.7	.9
	High Tube	16.0	10.3	5.2	3.3	1.0
	Low Tube	8.5	4.8	1.95	.95	.15
	Average	11.2	6.55	3.05	1.8	.44
SB	Manufacturers	12.2	7.6	4.0	2.7	.9
	High Tube	19.0	12.7	6.7	4.4	1.4
	Low Tube	11.9	6.8	3.2	1.9	.4
	Average	15.6	9.78	4.96	3.16	.94
C	Manufacturers	12.2	7.6	4.0	2.7	.9
	High Tube	14.5	8.9	4.5	2.8	.7
	Low Tube	8.8	3.9	1.9	1.0	.15
	Average	11.3	6.44	2.96	1.72	.37

All Values of  $I_p$  are milliamps

Table I  
 Physical Properties of the Polymers

Sample	$\bar{M}_n \times 10^{-3}$	$\bar{M}_w \times 10^{-3}$	$\bar{M}_z \times 10^{-3}$	$\bar{M}_v \times 10^{-3}$	$\bar{M}_w/\bar{M}_n$	$\bar{M}_z/\bar{M}_n$	$\bar{M}_v/\bar{M}_n$
1	1.2	1.5	1.8	1.4	1.25	1.50	1.33
2	1.5	2.0	2.5	1.8	1.33	1.67	1.50
3	2.0	2.8	3.5	2.4	1.40	1.75	1.60
4	2.5	3.5	4.5	3.0	1.40	1.80	1.60
5	3.0	4.0	5.0	3.6	1.33	1.67	1.50
6	3.5	4.5	5.5	4.0	1.29	1.57	1.43
7	4.0	5.0	6.0	4.5	1.25	1.50	1.33
8	4.5	5.5	6.5	5.0	1.22	1.44	1.30
9	5.0	6.0	7.0	5.5	1.20	1.40	1.27
10	5.5	6.5	7.5	6.0	1.18	1.36	1.25

\* Determined by endgroup analysis

Tube List	Tube	$I_p$ at $E_p$ of 120 V.	$I_p$ at $E_p$ of 150 V.	$I_p$ at $E_p$ of 200 V.	$I_p$ at $E_p$ of 250 V.	$I_p$ at $E_p$ of 300 V.
RA	Manufacturers	8.3	5.0	2.2	.75	0
	High Tube	13.4	8.3	4.5	1.7	.35
	Low Tube	10.3	6.5	3.4	1.3	.25
	Average	11.7	7.13	4.03	1.57	.283
RB	Manufacturers	8.3	5.0	2.2	.75	0
	High Tube	13.1	8.7	5.1	2.4	.5
	Low Tube	7.7	4.5	2.1	.55	.10
	Average	11.0	6.83	3.64	1.33	.23
RC	Manufacturers	8.3	5.0	2.2	.75	0
	High Tube	11.5	7.5	4.3	1.6	.3
	Low Tube	5.5	2.8	1.3	.4	.1
	Average	9.0	5.22	2.7	.88	.16
RD	Manufacturers	8.3	5.0	2.2	.75	0
	High Tube	13.4	8.5	4.7	1.9	.4
	Low Tube	7.8	4.5	2.0	.5	.05
	Average	9.8	5.86	2.87	.90	.142

All Values of  $I_p$  are Milliamps



Year	1900	1901	1902	1903	1904	1905
1900	27.4	28.5	29.7	30.8	31.9	33.0
1901	28.5	29.6	30.7	31.8	32.9	34.0
1902	29.6	30.7	31.8	32.9	34.0	35.1
1903	30.7	31.8	32.9	34.0	35.1	36.2
1904	31.8	32.9	34.0	35.1	36.2	37.3
1905	32.9	34.0	35.1	36.2	37.3	38.4
1906	34.0	35.1	36.2	37.3	38.4	39.5
1907	35.1	36.2	37.3	38.4	39.5	40.6
1908	36.2	37.3	38.4	39.5	40.6	41.7
1909	37.3	38.4	39.5	40.6	41.7	42.8
1910	38.4	39.5	40.6	41.7	42.8	43.9
1911	39.5	40.6	41.7	42.8	43.9	45.0
1912	40.6	41.7	42.8	43.9	45.0	46.1
1913	41.7	42.8	43.9	45.0	46.1	47.2
1914	42.8	43.9	45.0	46.1	47.2	48.3
1915	43.9	45.0	46.1	47.2	48.3	49.4
1916	45.0	46.1	47.2	48.3	49.4	50.5
1917	46.1	47.2	48.3	49.4	50.5	51.6
1918	47.2	48.3	49.4	50.5	51.6	52.7
1919	48.3	49.4	50.5	51.6	52.7	53.8
1920	49.4	50.5	51.6	52.7	53.8	54.9
1921	50.5	51.6	52.7	53.8	54.9	56.0
1922	51.6	52.7	53.8	54.9	56.0	57.1
1923	52.7	53.8	54.9	56.0	57.1	58.2
1924	53.8	54.9	56.0	57.1	58.2	59.3
1925	54.9	56.0	57.1	58.2	59.3	60.4
1926	56.0	57.1	58.2	59.3	60.4	61.5
1927	57.1	58.2	59.3	60.4	61.5	62.6
1928	58.2	59.3	60.4	61.5	62.6	63.7
1929	59.3	60.4	61.5	62.6	63.7	64.8
1930	60.4	61.5	62.6	63.7	64.8	65.9
1931	61.5	62.6	63.7	64.8	65.9	67.0
1932	62.6	63.7	64.8	65.9	67.0	68.1
1933	63.7	64.8	65.9	67.0	68.1	69.2
1934	64.8	65.9	67.0	68.1	69.2	70.3
1935	65.9	67.0	68.1	69.2	70.3	71.4
1936	67.0	68.1	69.2	70.3	71.4	72.5
1937	68.1	69.2	70.3	71.4	72.5	73.6
1938	69.2	70.3	71.4	72.5	73.6	74.7
1939	70.3	71.4	72.5	73.6	74.7	75.8
1940	71.4	72.5	73.6	74.7	75.8	76.9
1941	72.5	73.6	74.7	75.8	76.9	78.0
1942	73.6	74.7	75.8	76.9	78.0	79.1
1943	74.7	75.8	76.9	78.0	79.1	80.2
1944	75.8	76.9	78.0	79.1	80.2	81.3
1945	76.9	78.0	79.1	80.2	81.3	82.4
1946	78.0	79.1	80.2	81.3	82.4	83.5
1947	79.1	80.2	81.3	82.4	83.5	84.6
1948	80.2	81.3	82.4	83.5	84.6	85.7
1949	81.3	82.4	83.5	84.6	85.7	86.8
1950	82.4	83.5	84.6	85.7	86.8	87.9
1951	83.5	84.6	85.7	86.8	87.9	89.0
1952	84.6	85.7	86.8	87.9	89.0	90.1
1953	85.7	86.8	87.9	89.0	90.1	91.2
1954	86.8	87.9	89.0	90.1	91.2	92.3
1955	87.9	89.0	90.1	91.2	92.3	93.4
1956	89.0	90.1	91.2	92.3	93.4	94.5
1957	90.1	91.2	92.3	93.4	94.5	95.6
1958	91.2	92.3	93.4	94.5	95.6	96.7
1959	92.3	93.4	94.5	95.6	96.7	97.8
1960	93.4	94.5	95.6	96.7	97.8	98.9
1961	94.5	95.6	96.7	97.8	98.9	100.0

All values of  $\rho$  are positive

TABLE XI  
Sample Calculation of Power Output

<u>Ordinate</u>	<u>Voltage = ord. x 1.5v.</u>	<u><math>\frac{1}{2}</math></u>
0	0.0	0.0
.3	1.5	2.2
.6	2.9	8.6
.8	3.9	15.4
1.0	4.9	24.0
2.7	13.2	165.0
5.0	24.5	600.0
7.0	34.3	1175.0
10.0	49.0	2400.0
13.0	63.6	4030.0
15.0	73.5	5390.0
18.0	88.3	7760.0
20.0	98.0	9600.00
20.5	100.5	10050.0
21.0	103.0	10600.0
21.5	105.3	11160.0
22.0	107.8	11600.0
22.0	107.8	11600.0
21.7	106.2	11270.0
21.5	105.3	11060.0
22.0	107.8	11600.0

TABLE II  
 Specific Gravity of Liquid Nitrogen

Temperature in °C.	Specific Gravity
-196.0	0.808
-195.0	0.809
-194.0	0.810
-193.0	0.811
-192.0	0.812
-191.0	0.813
-190.0	0.814
-189.0	0.815
-188.0	0.816
-187.0	0.817
-186.0	0.818
-185.0	0.819
-184.0	0.820
-183.0	0.821
-182.0	0.822
-181.0	0.823
-180.0	0.824
-179.0	0.825
-178.0	0.826
-177.0	0.827
-176.0	0.828
-175.0	0.829
-174.0	0.830
-173.0	0.831
-172.0	0.832
-171.0	0.833
-170.0	0.834
-169.0	0.835
-168.0	0.836
-167.0	0.837
-166.0	0.838
-165.0	0.839
-164.0	0.840
-163.0	0.841
-162.0	0.842
-161.0	0.843
-160.0	0.844
-159.0	0.845
-158.0	0.846
-157.0	0.847
-156.0	0.848
-155.0	0.849
-154.0	0.850
-153.0	0.851
-152.0	0.852
-151.0	0.853
-150.0	0.854
-149.0	0.855
-148.0	0.856
-147.0	0.857
-146.0	0.858
-145.0	0.859
-144.0	0.860
-143.0	0.861
-142.0	0.862
-141.0	0.863
-140.0	0.864
-139.0	0.865
-138.0	0.866
-137.0	0.867
-136.0	0.868
-135.0	0.869
-134.0	0.870
-133.0	0.871
-132.0	0.872
-131.0	0.873
-130.0	0.874
-129.0	0.875
-128.0	0.876
-127.0	0.877
-126.0	0.878
-125.0	0.879
-124.0	0.880
-123.0	0.881
-122.0	0.882
-121.0	0.883
-120.0	0.884
-119.0	0.885
-118.0	0.886
-117.0	0.887
-116.0	0.888
-115.0	0.889
-114.0	0.890
-113.0	0.891
-112.0	0.892
-111.0	0.893
-110.0	0.894
-109.0	0.895
-108.0	0.896
-107.0	0.897
-106.0	0.898
-105.0	0.899
-104.0	0.900
-103.0	0.901
-102.0	0.902
-101.0	0.903
-100.0	0.904
-99.0	0.905
-98.0	0.906
-97.0	0.907
-96.0	0.908
-95.0	0.909
-94.0	0.910
-93.0	0.911
-92.0	0.912
-91.0	0.913
-90.0	0.914
-89.0	0.915
-88.0	0.916
-87.0	0.917
-86.0	0.918
-85.0	0.919
-84.0	0.920
-83.0	0.921
-82.0	0.922
-81.0	0.923
-80.0	0.924
-79.0	0.925
-78.0	0.926
-77.0	0.927
-76.0	0.928
-75.0	0.929
-74.0	0.930
-73.0	0.931
-72.0	0.932
-71.0	0.933
-70.0	0.934
-69.0	0.935
-68.0	0.936
-67.0	0.937
-66.0	0.938
-65.0	0.939
-64.0	0.940
-63.0	0.941
-62.0	0.942
-61.0	0.943
-60.0	0.944
-59.0	0.945
-58.0	0.946
-57.0	0.947
-56.0	0.948
-55.0	0.949
-54.0	0.950
-53.0	0.951
-52.0	0.952
-51.0	0.953
-50.0	0.954
-49.0	0.955
-48.0	0.956
-47.0	0.957
-46.0	0.958
-45.0	0.959
-44.0	0.960
-43.0	0.961
-42.0	0.962
-41.0	0.963
-40.0	0.964
-39.0	0.965
-38.0	0.966
-37.0	0.967
-36.0	0.968
-35.0	0.969
-34.0	0.970
-33.0	0.971
-32.0	0.972
-31.0	0.973
-30.0	0.974
-29.0	0.975
-28.0	0.976
-27.0	0.977
-26.0	0.978
-25.0	0.979
-24.0	0.980
-23.0	0.981
-22.0	0.982
-21.0	0.983
-20.0	0.984
-19.0	0.985
-18.0	0.986
-17.0	0.987
-16.0	0.988
-15.0	0.989
-14.0	0.990
-13.0	0.991
-12.0	0.992
-11.0	0.993
-10.0	0.994
-9.0	0.995
-8.0	0.996
-7.0	0.997
-6.0	0.998
-5.0	0.999
-4.0	1.000
-3.0	1.001
-2.0	1.002
-1.0	1.003
0.0	1.004

<u>Ordinate</u>	<u>Voltage =</u> <u>ord. x 4.9v.</u>	<u>E<sup>2</sup></u>
21.0	103.0	10609.0
21.0	103.0	10609.0
20.7	101.5	10302.0
20.3	99.5	9900.0
20.0	98.0	9604.0
19.0	93.1	8668.0
18.0	88.3	7796.0
17.0	83.4	6955.0
13.0	63.7	4058.0
10.0	49.0	2401.0
5.0	24.5	600.0
3.0	14.7	216.0
1.0	4.9	24.0
.2	.98	.96
0	0.0	0.0
0	0.0	0.0
0	0.0	0.0
0	0.0	0.0
0	0.0	0.0
Total		201469.2

Total E<sup>2</sup> = 201469.2

Average E<sup>2</sup> =  $\frac{201469.2}{39}$  = 5030 volts<sup>2</sup>

Number of ordinates = 39

P<sub>average</sub> =  $\frac{E_{av}^2}{R}$  =  $\frac{5030}{3000}$  = 1.675 Watt



[illegible]
$$\text{And } \text{ROI} = \frac{\text{OCF}}{\text{Investment}} = \frac{20}{100} = 20\%$$

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# APPENDIX II

## TABLE I

<u>Tube</u>	<u>ga before</u> <u>test</u>	$\Delta$ <u>ga for 37%</u> <u>Lower Chamber</u>	<u>% change</u> <u>in ga</u>
SB 1	4200	-2525	60.0
2	4300	-1300	30.2
3	3750	-1575	42.0
4	4550	-1550	34.1
5	4200	-1675	39.6
6	4500	-1950	43.3
7	4250	-1350	31.8
8	4400	-1400	31.8
9	4730	-1530	32.3
10	4050	-1330	32.8
11	4600	-1890	41.1
12	4400	-1700	38.6
13	4350	-1270	29.2
14	4550	-1600	35.2
15	3580	-1110	31.0
16	4600	-1500	32.6
17	4550	-1150	25.2
18	4550	-1850	40.7
20	4130	-1410	34.1
21	4400	-1460	33.2

# TABLE I

## TABLE I

Time	Temperature	Pressure	Volume
1.00	100.0	100.0	100.0
1.50	100.0	100.0	100.0
2.00	100.0	100.0	100.0
2.50	100.0	100.0	100.0
3.00	100.0	100.0	100.0
3.50	100.0	100.0	100.0
4.00	100.0	100.0	100.0
4.50	100.0	100.0	100.0
5.00	100.0	100.0	100.0
5.50	100.0	100.0	100.0
6.00	100.0	100.0	100.0
6.50	100.0	100.0	100.0
7.00	100.0	100.0	100.0
7.50	100.0	100.0	100.0
8.00	100.0	100.0	100.0
8.50	100.0	100.0	100.0
9.00	100.0	100.0	100.0
9.50	100.0	100.0	100.0
10.00	100.0	100.0	100.0
10.50	100.0	100.0	100.0
11.00	100.0	100.0	100.0
11.50	100.0	100.0	100.0
12.00	100.0	100.0	100.0
12.50	100.0	100.0	100.0
13.00	100.0	100.0	100.0
13.50	100.0	100.0	100.0
14.00	100.0	100.0	100.0
14.50	100.0	100.0	100.0
15.00	100.0	100.0	100.0
15.50	100.0	100.0	100.0
16.00	100.0	100.0	100.0
16.50	100.0	100.0	100.0
17.00	100.0	100.0	100.0
17.50	100.0	100.0	100.0
18.00	100.0	100.0	100.0
18.50	100.0	100.0	100.0
19.00	100.0	100.0	100.0
19.50	100.0	100.0	100.0
20.00	100.0	100.0	100.0

<u>Tube</u>	<u>gm after test</u>	<u>final relative position of gm (actual)</u>	<u>final relative position of gm (predicted)</u>
1	3340	9th	10th
2	3070	8th	11th
3	3200	10th	9th
4	3900	11th	2nd
5	3820	8th	7th
6	4420	1st	8th
7	3860	7th	5th
8	4300	2nd	3rd
9	4200	3rd	1st
10	3680	5th	6th
11	2930	5th	6th
12	2600	9th	8th
13	3100	11th	3rd
14	3100	11th	11th
15	2850	7th	10th
16	3700	1st	2nd
17	3500	2nd	1st
18	3150	3rd	7th
20	2700	8th	9th
21	2900	6th	5th



Leaf number collected (number) on 30	Leaf number collected (number) on 30	Leaf number collected (number) on 30	Leaf number collected (number) on 30
1000	1000	1000	1000
1001	1001	1001	1001
1002	1002	1002	1002
1003	1003	1003	1003
1004	1004	1004	1004
1005	1005	1005	1005
1006	1006	1006	1006
1007	1007	1007	1007
1008	1008	1008	1008
1009	1009	1009	1009
1010	1010	1010	1010
1011	1011	1011	1011
1012	1012	1012	1012
1013	1013	1013	1013
1014	1014	1014	1014
1015	1015	1015	1015
1016	1016	1016	1016
1017	1017	1017	1017
1018	1018	1018	1018
1019	1019	1019	1019
1020	1020	1020	1020
1021	1021	1021	1021
1022	1022	1022	1022
1023	1023	1023	1023
1024	1024	1024	1024
1025	1025	1025	1025
1026	1026	1026	1026
1027	1027	1027	1027
1028	1028	1028	1028
1029	1029	1029	1029
1030	1030	1030	1030

<u>Tube</u>	<u>Relative position</u> <u>original gm</u>
1	7th
2	5th
3	9th
4	2nd
5	7th
6	3rd
7	0th
8	4th
9	1st
10	8th
11	1st
12	3rd
13	4th
14	2nd
15	6th
16	1st
17	2nd
18	2nd
20	5th
21	3rd

Relative position on section	Order
107	1
108	2
109	3
110	4
111	5
112	6
113	7
114	8
115	9
116	10
117	11
118	12
119	13
120	14
121	15
122	16
123	17
124	18
125	19
126	20
127	21

TABLE I (continued)

<u>Tube</u>	<u>gm before test</u>	<u>gm for 37% Lower Rheater</u>	<u>% change in gm</u>	<u>gm after test</u>
RD 1	3630	825	77.3	3600
2	4300	800	81.3	4270
3	4000	1150	71.3	3700
4	3800	1275	46.2	3730
5	4550	1950	57.1	4600
6	3620	1950	46.2	3300
7	4150	1700	59.0	3950
8	3670	2550	30.5	3520
9	3900	800	79.5	3560
10	4200	660	84.2	4400

	<u>Actual relative gm after test</u>	<u>Predicted relative gm after test</u>	<u>Original relative position of gm</u>
1	7th	10th	9th
2	3rd	5th	2nd
3	6th	6th	5th
4	5th	7th	7th
5	1st	1st	1st
6	10th	4th	10th
7	4th	3rd	4th
8	9th	2nd	8th
9	8th	<del>9th</del>	6th
10	2nd	8th	3rd



Table I (continued)

Tube	mm before test	mm for 312 lower position in mm	mm change in mm	mm after test
10	1000	600	40.0	1040
9	1000	600	39.2	1039
8	1070	520	30.7	1100
7	1100	470	29.0	1129
6	1200	420	26.4	1226
5	1200	420	24.7	1224
4	1200	415	16.6	1216
3	1200	410	17.3	1217
2	1200	400	41.3	1241
1	1200	400	41.0	1241

Tube	Actual relative mm after test	Projected relative mm after test	Original relative position of mm
1	700	1000	300
2	700	900	200
3	600	800	200
4	600	700	100
5	500	600	100
6	400	500	100
7	300	400	100
8	200	300	100
9	100	200	100
10	100	100	100

<u>Tube</u>	<u>gm before test</u>	<u>gm for 37% lower Rheater</u>	<u>% change in gm</u>	<u>gm after test</u>
RC 1	3630	605	16.7	3300
2	3450	2900	84.5	3420
3	4550	820	18.0	3750
4	3420	1270	37.2	3600
5	3900	1700	43.6	3850
6	3800	1580	41.6	3320
7	3350	650	19.4	3280
8	3440	1940	56.4	3430
9	3100	2250	72.6	3400
10	3620	2870	79.3	3700

Order No.	Quantity	Unit Price	Total Price	Order No.	Quantity	Unit Price	Total Price
0001	1.00	100.00	100.00	0001	1.00	100.00	100.00
0002	2.00	200.00	400.00	0002	2.00	200.00	400.00
0003	3.00	300.00	900.00	0003	3.00	300.00	900.00
0004	4.00	400.00	1600.00	0004	4.00	400.00	1600.00
0005	5.00	500.00	2500.00	0005	5.00	500.00	2500.00
0006	6.00	600.00	3600.00	0006	6.00	600.00	3600.00
0007	7.00	700.00	4900.00	0007	7.00	700.00	4900.00
0008	8.00	800.00	6400.00	0008	8.00	800.00	6400.00
0009	9.00	900.00	8100.00	0009	9.00	900.00	8100.00
0010	10.00	1000.00	10000.00	0010	10.00	1000.00	10000.00

Tube	Actual relative gm after test	Predicted relative gm after test	Original rela- tive position of gm
R6 1	8th	2nd	4th
2	6th	9th	6th
3	2nd	1st	1st
4	4th	6th	8th
5	1st	3rd	2nd
6	9th	4th	3rd
7	10th	5th	9th
8	5th	8th	7th
9	7th	10th	10th
10	3rd	7th	5th



Index	Actual relative to other part	Predicted relative to other part	Relative error five positions of 10
1	100	100	100
2	100	100	100
3	100	100	100
4	100	100	100
5	100	100	100
6	100	100	100
7	100	100	100
8	100	100	100
9	100	100	100
10	100	100	100
11	100	100	100
12	100	100	100
13	100	100	100
14	100	100	100
15	100	100	100
16	100	100	100
17	100	100	100
18	100	100	100
19	100	100	100
20	100	100	100

TABLE II

<u>Tube</u>	<u><math>r_p</math> at 6.3V</u>	<u><math>r_p</math> at 4.0V</u>	<u><math>\Delta r_p</math></u>
5A 11	3510	6450	2940
12	3640	9100	5460
13	5125	11100	5975
14	4080	5880	1800
15	5125	8710	3585
16	4875	15400	10525
17	4000	10350	6350
18	4545	21050	16505
19	5125	9540	4415
20	4000	8350	4350
RA 1	5260	9520	3260
2	4650	11750	7100
3	3775	14300	10525
4	4080	13330	9250
5	3920	25000	21080
6	4160	9100	4840
8	4250	28600	24350
9	4350	13340	8990
10	4445	18200	13755

# TABLE II

No. of Observations	1941		1942		Total
	Jan	Feb	Jan	Feb	
1	100	100	100	100	400
2	100	100	100	100	400
3	100	100	100	100	400
4	100	100	100	100	400
5	100	100	100	100	400
6	100	100	100	100	400
7	100	100	100	100	400
8	100	100	100	100	400
9	100	100	100	100	400
10	100	100	100	100	400
11	100	100	100	100	400
12	100	100	100	100	400
13	100	100	100	100	400
14	100	100	100	100	400
15	100	100	100	100	400
16	100	100	100	100	400
17	100	100	100	100	400
18	100	100	100	100	400
19	100	100	100	100	400
20	100	100	100	100	400
21	100	100	100	100	400
22	100	100	100	100	400
23	100	100	100	100	400
24	100	100	100	100	400
25	100	100	100	100	400
26	100	100	100	100	400
27	100	100	100	100	400
28	100	100	100	100	400
29	100	100	100	100	400
30	100	100	100	100	400
31	100	100	100	100	400
32	100	100	100	100	400
33	100	100	100	100	400
34	100	100	100	100	400
35	100	100	100	100	400
36	100	100	100	100	400
37	100	100	100	100	400
38	100	100	100	100	400
39	100	100	100	100	400
40	100	100	100	100	400
41	100	100	100	100	400
42	100	100	100	100	400
43	100	100	100	100	400
44	100	100	100	100	400
45	100	100	100	100	400
46	100	100	100	100	400
47	100	100	100	100	400
48	100	100	100	100	400
49	100	100	100	100	400
50	100	100	100	100	400

<u>Tube</u>	<u>gm after test</u>	<u>gm before test</u>	<u><math>\Delta</math> gm due 20 hour test</u>
SA11	2730	4170	-1440
12	2900	3900	-1000
13	2630	3270	-640
14	2590	3650	-1060
15	2500	3370	-870
16	2150	3300	-1150
17	2700	3700	-1000
18	2450	3480	-1230
19	2700	3350	-650
20	2830	3600	-770
RA1	3940	4150	-210
2	3700	3840	-140
3	3930	4220	-290
4	4280	4400	-120
5	4730	4850	-120
6	3320	3630	-310
8	3450	4080	-630
9	3950	4320	-370
10	3820	4000	-180





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He attended The Episcopal High School, Alexandria, Virginia for two years, and Culver Military Academy, Culver, Indiana for three years. He graduated from Culver in June 1937, and returned the following year for Junior College.

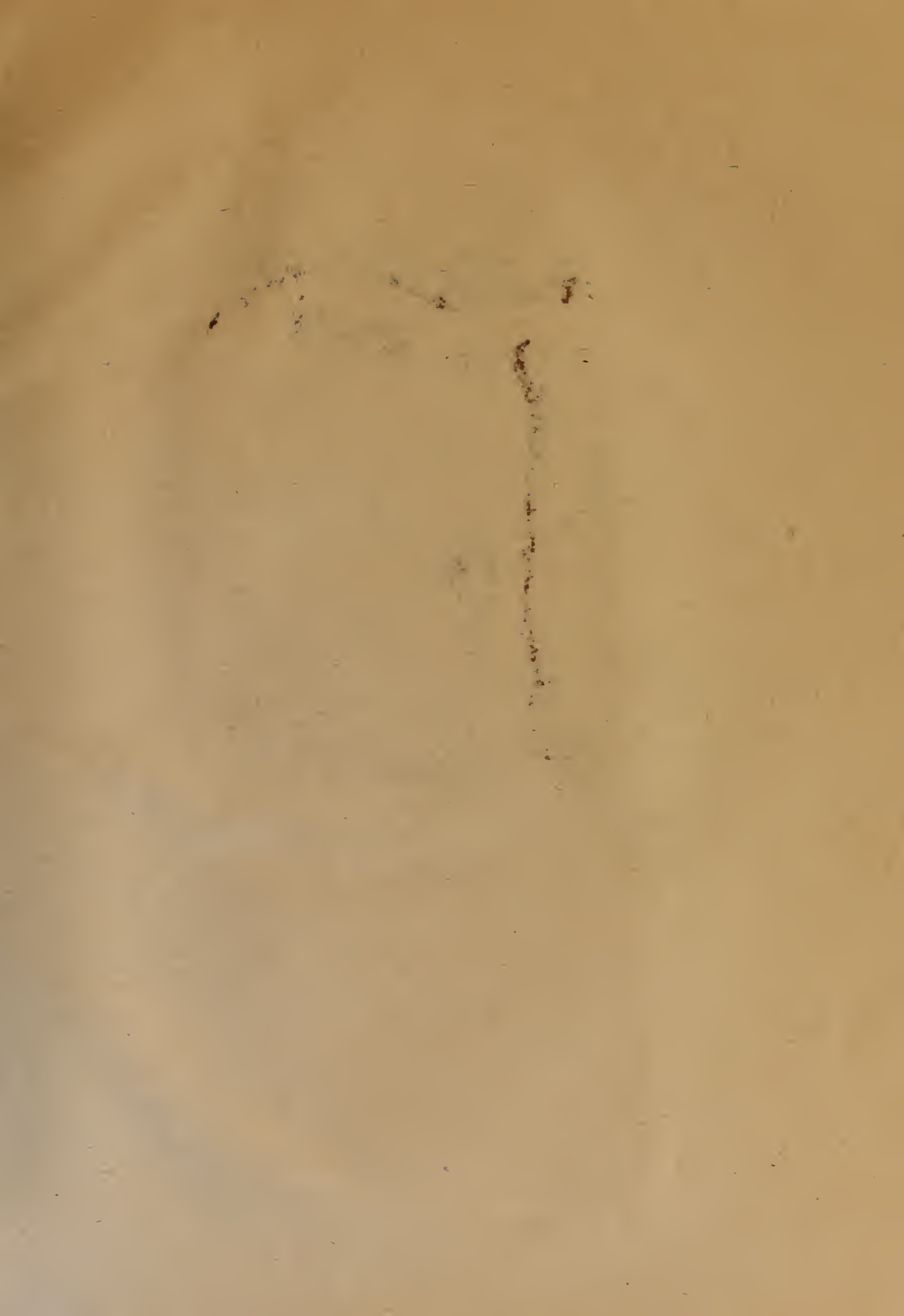
In July 1938 he entered the U.S. Naval Academy and was graduated with Bachelor of Science Degree in December 1941. Since graduation he has served as a Naval Officer.

He entered the U.S. Naval Postgraduate School, Annapolis, Maryland in July 1946 and in September 1947 entered The Johns Hopkins Engineering School as a graduate student in Electrical Engineering under the sponsorship of the Bureau of Ordnance, U.S. Navy.



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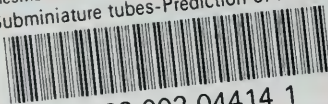
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